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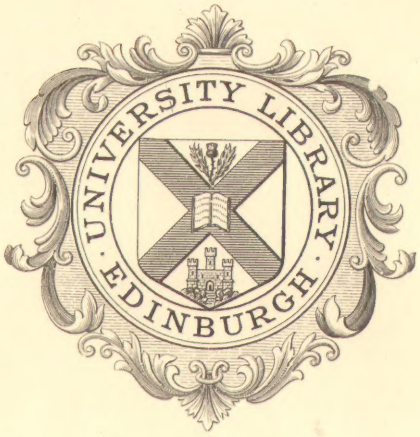

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Summary of Progress

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I.—THE SCOTTISH MILLSTONE GRIT AND ITS POSITION IN THE ZONAL SUCCESSION

BY

M. MACGREGOR, M.A., D.Sc., and J. PRINGLE, D.Sc.

Plate I.

IN view of recent work on the zonal succession in the Millstone Grit of the English and Welsh coalfields it seems desirable to summarize the evidence that has so far been obtained within the Scottish area. The subject matter of the present paper is subdivided as follows:—

1. The Scottish Millstone Grit
2. The Millstone Grit of the Pennine area and the Zonal Succession
3. Application of Zonal Scheme to Scotland
4. General Conclusions.

1. THE SCOTTISH MILLSTONE GRIT

In his account of the Millstone Grit of the Midlothian Coalfield, contributed to the first edition of 'The Geology of the Neighbourhood of Edinburgh,'[1] Howell stated:—

"This division of the Carboniferous formation has never before been classed as a separate group in any map or memoir published of this district, although the thick series of sandstones and conglomerates which here represent it have been noticed." He correlated for the first time the barren sandstones of Joppa, Roslin and Hawthornden with the Millstone Grit of England, and the overlying coal-bearing strata with the Coal Measures of Newcastle and Durham. He supported this correlation by pointing out that in these higher strata "are found the ordinary species of *Unio*, or rather *Anthracosia acuta*, Sby., the same being found in the English coal-fields."[2] While palaeontological criteria were thus utilized to define the upper limit of the Series, the lower limit was arbitrarily drawn at the top of No. 6 Limestone, which thus *ipso facto* became the highest member of the Carboniferous Limestone Series. On the completion of the mapping of the district the following subdivisions in descending order were recognized, and distinguished on

[1] (*Mem. Geol. Surv.*), 1861, p. 103; the corresponding one-inch Sheet—the first published Sheet of the Geological Survey in Scotland—appeared in 1859.

[2] *Ibid.*, p. 105.

the Survey maps by separate colours:—Coal Measures, Millstone Grit[1] and Carboniferous Limestone Series. This last was shown to include three distinct groups, the Upper Limestones, the Edge Coals[2] and the Lower Limestones. Beneath the Carboniferous Limestone Series were mapped still Lower Carboniferous rocks—the Calciferous Sandstone Series of modern nomenclature—but since they do not affect the present question no further reference to them need be made.

The mapping of other portions of the Scottish Coalfields proceeded on the lines adopted in Midlothian. No. 6 Limestone was identified with the Castlecary Limestone of the West of Scotland, and this latter designation is now generally applied to the highest member of the Upper Limestone Group. The Castlecary Limestone is easily recognized over large areas in the Midland valley; it forms a convenient and definite datum-line throughout the greater part of the coalfields.[3] The Millstone Grit thus everywhere comprised the barren arenaceous strata overlying this horizon and extending upwards to the base of the Coal Measures. This upper limit in each of the coalfields was drawn at the base of the coal-bearing sediments with their included musselbands, and, although in each district the line is more or less arbitrary, there is no reason to doubt the general stratigraphical equivalence of the boundaries adopted.

In 1893 Kidston[4] published an account of his studies of the flora of the Carboniferous rocks of Scotland and showed that a palaeontological 'break' took place near the top of the lower third of the Millstone Grit. Traquair's[5] researches on the estuarine fish fauna brought him independently to the same conclusion. These results led to a subdivision of the Carboniferous rocks of Scotland into a lower portion including the Calciferous Sandstone Series, the Carboniferous Limestone Series and the lower third (approximately) of the Millstone Grit, and an upper portion including the upper two-thirds of the Millstone Grit and the Coal Measures. This subdivision into Lower and Upper Carboniferous has been indicated on the vertical sections attached to the revised one-inch maps of the coalfields.

Kidston was unable to offer a satisfactory explanation for the sudden disappearance of one flora and the equally sudden appearance of another. It seems clear, however, that the palaeontological 'break' must be correlated with the evidence for marked

---

[1] Also known in the Midlothian Coalfield as the Roslin Sandstone Series.

[2] The Limestone Coal Group of present-day nomenclature. The Edge Coals were so named by R. Bald (See 'Additional Observations on the Coal Field of Clackmannanshire, and a Description of the absolute Shape and Form of the Coal Fields in Great Britain,' *Mem. Wernerian Nat. Hist. Soc.*, vol. iii, 1821, pp. 123-155) on account of their high degree of inclination. Bald's "Edge Coals," however, included the lower seams of the Coal Measures.

[3] In certain districts where the Castlecary Limestone is absent through erosion, an arbitrary line had to be drawn.

[4] Kidston, R. 'On the Various Divisions of the British Carboniferous Rocks as determined by their Fossil Flora,' *Proc. Roy. Physical Soc., Edin.*, vol. xii, 1894, pp. 183-257.

[5] Traquair, R. H. 'List of the Fossil Dipnoi and Ganoidei of Fife and the Lothians,' *Proc. Roy. Soc. Edin.*, vol. xvii, 1891, pp. 385-400; 'On the Distribution of Fossil Fish-remains in the Carboniferous Rocks of the Edinburgh District,' *Trans. Roy. Soc., Edin.*, 1903, vol. xl, pp. 687-707.

unconformity within the Millstone Grit Series obtained in recent years. It has been shown that in a number of districts the Lower Carboniferous rocks have been uplifted and subjected to a varying amount of denudation.[1] Attention may also be drawn here to the fact that over a wide area in the West of Scotland[2] the Millstone Grit is represented, largely or wholly, by basaltic lavas poured out over a low lying and slowly subsiding area, and subjected at times to contemporaneous subaerial weathering.

2. The Millstone Grit of the Pennine Area and the Zonal Succession

An excellent account of the Millstone Grit of part of the Pennine Area has been given by Dr. W. B. Wright[3] and his colleagues in ' The Geology of the Rossendale Anticline ' (*Mem. Geol. Surv.*, 1927). As originally defined by Hull and Green,[4] the Millstone Grit included four main horizons :—

First Grit or Rough Rock
Second Grit (Haslingden or Lower Flags of Lancashire)
Third Grit (Escarpment Grit)
Fourth Grit (Main Millstone or Kinderscout Grit)

To these beds was later added a fifth grit known as the Shale-Grit or Farey's Grit. In the Mid-Pennine area, however, still lower grits were subsequently included and the total thickness of the Series was increased by over 1,000 ft. In the absence of any evidence for a stratigraphical or palaeontological break, the term Millstone Grit Series was extended to include these lower beds.

Mr. Bisat's[5] utilization of the time-range of certain goniatites as a basis of classification has now placed the question of correlation on a sounder foundation. He has established in descending order the following zones :—

Zone of Gastrioceras	(G)
Zone of Reticuloceras	(R)
Zone of Homoceras	(H)
Zone of Eumorphoceras	(E)

The boundary between the Upper and Lower Carboniferous goniatite faunas was taken by Mr. Bisat at the base of Zone E, since

[1] See Macgregor, M. ' Scottish Carboniferous Stratigraphy,' *Trans. Geol. Soc. Glasgow*, 1930, vol. xviii, part iii, pp. 461-463 ; G. Ross, ' An Unconformity of Millstone Grit Age in the Douglas Coalfield, Lanarkshire,' *in* ' Summary of Progress ' for 1930—Part II (*Mem. Geol. Surv.*), 1931, pp. 39-43 ; J. Pringle and J. E. Richey,' Carboniferous Rocks of the Thornhill Basin, Dumfriesshire,' *ibid.*, pp. 25-33 ; C. H. Dinham, ' Economic Geology of the Stirling and Clackmannan Coalfield' (*Mem. Geol. Surv.*), 1932, pp. 113-116.

[2] See ' Geology of North Ayrshire' (*Mem. Geol. Surv.*), 1930, Fig. 25, p. 200.

[3] For a general account of the Millstone Grit in Britain, see W. B. Wright *in* ' Handbook of the Geology of Great Britain,' 1929, pp. 251-259.

[4] Hull, E., and A. H. Green, ' On the Millstone Grit of North Staffordshire and the adjoining parts of Derbyshire, Cheshire and Lancashire,' *Quart. Journ. Geol. Soc.*, vol. xx, 1864, pp. 242-267.

[5] Bisat, W. S., ' The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, pt. i, 1924 (p. 40 of reprint).

this line coincides with the extinction of *Goniatites* (*sensu stricto*), and the first appearance of *Eumorphoceras*. This line has also been adopted for the base of the Millstone Grit Series in recent Survey memoirs.[1] The Millstone Grit Series is taken as including all the beds in Zones E, H, and R and the lower part of Zone G.

3. Application of Zonal Scheme to Scotland

Mr. Bisat identified certain goniatites obtained from a horizon 30 ft. above the Castlecary Limestone in the Bilston Burn, Midlothian, as probably *Anthracoceras glabrum* and stated that in his opinion this species indicates a horizon high in Zone E or low in Zone H.[2] Late mutations of the same species have since been obtained in a boring in N.E. Stirlingshire close above the Castlecary Limestone.[3] Unfortunately no goniatites have so far been recorded from the higher marine bands of the Scottish Millstone Grit. It has been ascertained, however, that Lower Carboniferous plants range in N.E. Stirlingshire up to a level a few feet above No. 3 Marine Band, and it may be not without significance that the lamellibranchs and gastropods forming the 'Nebraskan Fauna' of Wheelton Hind[4] disappear at the same horizon.[5] The dividing line appears to fall between No. 3 and No. 5 Marine Bands since *Lepidophloios scoticus* Kidston and *Spathulopteris sp.* were obtained in No. 35 Carronhall Bore at a position 6 feet above No. 3 Band and 125 feet below a bed yielding the Upper Carboniferous plant *Calamites schützeiformis* K. and J. Similarly, *Sphenopteris striata* Gothan was found 51 feet above No. 3 Band. Other striking instances of the replacement of the Lower Carboniferous flora by Upper Carboniferous plants have been observed in East Lothian,[6] in Ayrshire, and in Dumfriesshire. In the Caaf Water in Ayrshire,[7] a Lower Carboniferous flora occurs in rocks a little more than 30 feet below the Millstone Grit lavas, while Upper Carboniferous plants were obtained from the Ayrshire Bauxitic Clay above the lavas. Again, in the Polhote Burn in the Sanquhar Coalfield, Dumfriesshire, an Upper Carboniferous flora consisting mainly of *Calamites*, *Lepidodendron*, *Sigillaria*, *Sphenopteris* and *Neuropteris*, is found about 25 feet above a bed yielding Lower Carboniferous plants and marine shells. In no instance, however, have Upper Carboniferous plants been found in association with Lower Carboniferous forms.

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[1] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, pp. 8 and 9 and Fig. 6; 'The Country around Holmfirth and Glossop' (*Mem. Geol. Surv.*), 1933, pp. 12-14.

[2] Bisat, W. S., 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, pt. i, 1924 (p. 16 of reprint).

[3] 'Economic Geology of the Stirling and Clackmannan Coalfield' (*Mem. Geol. Surv.*), 1932, p. 114. This memoir gives an account of marine bands (Nos. 0-6) in the Millstone Grit of N.E Stirlingshire where this series attains its greatest development.

[4] Hind, W., 'On the Lamellibranchs and Gasteropod Fauna found in the Millstone Grit of Scotland,' *Trans. Roy. Soc. Edin.*, 1908, vol. xlvi, pp. 331-359.

[5] 'Economic Geology of the Stirling and Clackmannan Coalfield' (*Mem. Geol. Surv.*), 1932, pp. 117-119.

[6] 'Geology of East Lothian' (*Mem. Geol. Surv.*), 1910, p. 157.

[7] 'Geology of North Ayrshire' (*Mem. Geol. Surv.*), 1930, p. 201.

Non-marine lamellibranchs are comparatively rare in the Scottish Millstone Grit. With the exception of two species recorded from near the top of the Millstone Grit of East Lothian, no fresh-water 'mussels' have been found in this Series in the East of Scotland. In Lanarkshire, however, Dr. J. Weir and Mr. D. Leitch have provisionally identified certain small species of *Anthracomya* from the Millstone Grit of the Douglas Coalfield as *A.* cf. *bellula* Bolton. The shells were collected by Survey officers at a depth of about 270 feet below shales containing *Carbonicola pseudorobusta* Trueman in the same bore. Again, in Ayrshire, three musselbands have been recently found at depths of 48, 90 and 318 feet below the base of the Coal Measures. At the lowest level *Carbonicola* cf. *centralis* (J. de C. Sow.), *C.* cf. *communis* D. and T., and *C.* cf. *subconstricta* (J. Sow.), were obtained by one of the writers in shales that lie some 150 feet above the top of the Carboniferous Limestone Series.

Recent information having a bearing on the zonal position of the highest members of the Upper Limestone Group may be referred to here. In this connexion certain specimens from these beds included in the John Smith Collection, now the property of the Scottish Survey, are recorded for the first time. Thus, a marine band, which immediately underlies the Millstone Grit (Lower Coal Measures of Smith) in the Muirfoot Burn near New Cumnock in Ayrshire, includes the following species:—*Lingula mytiloides* J. Sow., *Limatulina scotica* Hind (topotypes), *Nucula gibbosa* Flem., *Nuculana attenuata* (Flem.), *N. laevistriata* Meek and Worthen, *Bellerophon anthracophilus* Frech, *Euphemus urei* (Flem.), mut. *ardenensis* Weir, *Anthracoceras* cf. *glabrum* Bisat, and *Tylonautilus nodiferus* (Armstrong). The beds are no longer well exposed, but the horizon is probably that of the Calmy Limestone rather than the higher Castlecary Limestone. Again from the Calmy Limestone, at Dubbs near Barrhead, *T. nodiferus* was also collected by Smith along with a single specimen of *Eumorphoceras bisulcatum* Girty. Finally, from the Arden (Calmy) Limestone of Arden, a locality which has yielded *T. nodiferus* to other collectors, the Smith Collection includes *Anthracoceras paucilobum* (Phill.).

From the Castlecary Limestone, *T. nodiferus* has been recorded at a number of localities, and the occurrence of this nautiloid has been noted in a bore in N.E. Stirlingshire,[1] where it was found in a marine band (No. 0) a few fathoms above the Castlecary Limestone.

From the evidence outlined above, certain tentative conclusions may be drawn. The persistence of a Lower Carboniferous flora up to No. 3 Marine Band (p. 4), where both the plants and the so-called Nebraskan fauna disappear, seems to us to indicate that the beds as high as this position must lie in Zone E. In parts of

[1] 'Economic Geology of the Stirling and Clackmannan Coalfield' (*Mem. Geol. Surv.*), 1932, p. 117.

England and Wales, the floral change is known to take place within Zone H,[1] so that the occurrence of Upper Carboniferous plants between Nos. 3 and 5 Marine Bands of N.E. Stirlingshire suggests that the latter may fall within this Zone. No goniatites, however, have been found in the higher marine bands, and there is as yet no definite evidence to show that Zones H and R are anywhere represented in Scotland. Indeed the presence of 'mussels' belonging to the Ovalis Zone *s. str.* in the Millstone Grit of South Ayrshire and Lanarkshire (p. 5) may be taken to indicate, that here, at least, Zones H and R are absent.

The application of the zonal classification adopted in the Pennine area (p. 3) would therefore produce in Scotland anomalous results. For example, the Upper Limestone Group and part, if not all, of the Limestone Coal Group would fall within Zone E, and are therefore equivalent to the lower part of the Millstone Grit Series of the Pennines; in other words they form part of the Upper Carboniferous. On the other hand, the boundary between the Lower and Upper Carboniferous is drawn in Scotland at the level of the palaeontological 'break' demonstrated by Kidston and Traquair, a level which we suggest may be at or near the *top* of Zone E.[2]

As regards the upper two-thirds of the Scottish Millstone Grit, it is now possible to compare the succession of non-marine lamellibranchs with that established by Davies and Trueman.[3] Specimens obtained from the Millstone Grit of Lanarkshire and Ayrshire[4] indicate a position within the Ovalis Zone *s. str.*, and since the lowest of these musselbands occurs not far above the top of the Carboniferous Limestone Series they add support to the view that a stratigraphical break of considerable magnitude occurs within the Millstone Grit. We have already referred (p. 3) to the evidence for marked unconformity in several districts, and for the occurrence in the West of Scotland of subaerially weathered basaltic lavas. It would appear, therefore, that actual emergence of portions of the Scottish area took place during the deposition in the Pennine region of the sediments included within Zone R and the greater part, if not the whole, of Zone H.

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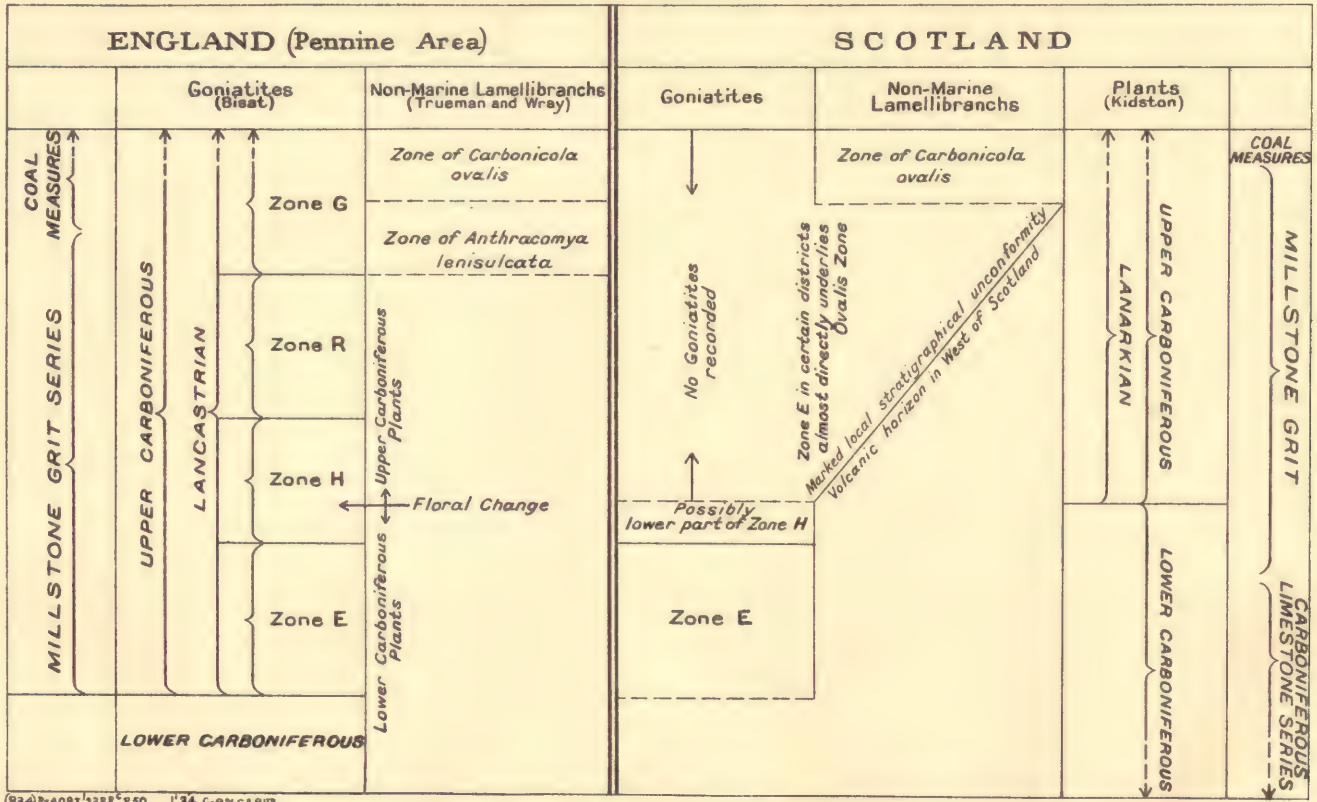
[1] See Bisat, W., *ibid*, p. 10; S. W. Hester, 'The Millstone Grit Succession in North Staffordshire' *in* 'Summary of Progress' for 1931—Part II (*Mem. Geol. Surv.*), 1932, pp. 34-48; J. Pringle and J. W. Jackson, '*Tylonautilus nodiferus gen. nov.*; A Carboniferous Guide Fossil,' *The Naturalist*, December, 1928, p. 377.

[2] Goniatites recently collected from borings suggest that E_2 may extend as far down as the shales overlying the Index Limestone; see 'Summary of Progress' for 1932—Part I (*Mem. Geol. Surv.*), 1933, pp. 25 and 73.

[3] 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures and a Discussion of their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, pp. 210-257; See also D. A. Wray and A. E. Trueman, 'The Non-Marine Lamellibranchs of the Upper Carboniferous of Yorkshire and the Zonal Sequence,' in 'Summary of Progress' for 1930—Part III (*Mem. Geol. Surv.*), 1931, pp. 70-92.

[4] See page 5. No records have as yet been obtained from the East of Scotland. In this connexion it is of interest to point out that few musselbands have been found in the Coal Measures of Midlothian and Fife.

ZONAL CLASSIFICATION OF MILLSTONE GRIT



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4. General Conclusions

The results of this study of the Scottish Millstone Grit in relation to the zonal succession established in the Pennine area are summarized in diagrammatic form in Plate I. This diagram shows that the subdivision into Lower and Upper Carboniferous is based in Scotland on the evidence of the fossil plants, and in the Pennine area on that of the goniatites. The higher beds of the Scottish Lower Carboniferous have yielded goniatites which are referred to the upper part of Zone E or the lower part of Zone H (p. 4). No representatives, however, of the higher zones of the goniatite time-scale have so far been recorded within the Scottish succession, but the presence of beds of Zone G age is indicated by the occurrence of freshwater lamellibranchs belonging to the Ovalis Zone. It has already been pointed out that the adoption of the base of Zone E as the lower limit of the Millstone Grit would place within that Series the Upper Limestone Group and perhaps the whole of the Limestone Coal Group of Scotland. On the other hand, there is a certain amount of evidence to show that in parts of England and Wales there is a transition within Zone H from a Lower to an Upper Carboniferous flora (p. 6); and in this connexion it may be suggested that if the goniatite-boundary had been drawn at the top of Zone E instead of at the base, Mr. Bisat's Lancastrian would have agreed closely with Kidston's Lanarkian.[1]

The Scottish Millstone Grit, we would point out in conclusion, was originally correlated with the Millstone Grit of England at a time when that formation was somewhat loosely regarded as lying above the Mountain Limestone and below the Coal Measures. Its boundaries in Scotland were defined and mapped for several years previous to Hull and Green's work in the Pennine area and to that extent the Scottish classification may claim priority to that adopted in England. The writers, while fully recognizing the great importance of a classification based on the time-ranges of plants and animals for correlation over wide areas, wish, however, to emphasize the fact that in preparing maps of the coalfields it has been found essential to establish and trace the boundaries of groups of strata and to leave the application of refined chronological schemes for discussion in the memoirs. Especially is this the case in Scotland and the North of England where important coals are being, or have been, worked in the Carboniferous Limestone Series, and where the interpretation of borings so often depends upon the recognition of definite lithological horizons and sequences. The practice in Scotland is to follow the original lithological classification adopted and defined by the early surveyors. The stratigraphical units made use of are Coal Measures, Millstone Grit, Upper Limestone Group, Limestone Coal Group (Edge Coal Group), Lower Limestone Group and Calciferous Sandstone Series. The boundaries of these units have long been established and their practical value is daily demonstrated in our coalfield work.

[1] Cf. Macgregor, M., 'Scottish Carboniferous Stratigraphy,' *Trans. Geol. Soc. Glasgow*, 1930, vol. xviii, part iii, Fig. 5, p. 483.

II.—THE FRESH-WATER FAUNA OF THE LOWER COAL MEASURES OF LANCASHIRE

BY

W. B. WRIGHT, Sc.D.

Plate II. : Text-Figures 1-7.

INTRODUCTION

THERE is no break either stratigraphical or palaeontological between the Millstone Grit Series and the Lower Coal Measures of Lancashire. The same types of sediment are found in both and the goniatites of one series pass upwards into the other with even less evolutional change than is observed in the beds immediately below. *Gastrioceras cumbriense* Bisat and *Gastrioceras listeri* (Martin), both of which occur in the Haslingden Flags, ascend as high as the Bullion Mine Marine Band, the only change being the rarity of the former and abundance of the latter on the higher horizon.

Although the development of fresh or brackish water faunas becomes a marked feature of the Carboniferous succession about this horizon in Lancashire and a great part of England, these alternate with marine faunas, and are known to make their first appearance in both Yorkshire and Lancashire about 300 ft. below the base of the so-called Coal Measures. Trueman[1] has described two species of *Carbonicola* from this level in Yorkshire, and on much the same horizon in Lancashire, at the top of the Holcombe Brook Series, specimens of *Naiadites* have been found.

Passing upward through the succession which forms the upper portion of the Millstone Grit in Lancashire, the next non-marine horizon is that between the Upper Haslingden Flags and Rough Rock, from which Bolton obtained the types of *Anthracomya bellula*.[2] These fossils are not always easy to find, being scattered through mudstone, but they have been proved to occur in several localities west of Blackburn as well as in the type locality in Rossendale. They occur also immediately above the Six Inch Mine, in the freshwater bed between the coal and its overlying marine band, thus bridging the horizon that is assumed as the base of the Lower Coal Measures. There is consequently no palaeontological change by which this horizon can be recognized.

STRATIGRAPHY OF THE LOWER COAL MEASURES OF LANCASHIRE

The stratigraphy of the Lower Coal Measures, so obvious and so easily interpreted in the Rossendale Anticline and north of

[1] Trueman, A. E., 'Some new Carboniferous Lamellibranchs,' *Ann. Mag. Nat. Hist.*, Ser. 10, vol. iv, 1929, pp. 87-89.

[2] Bolton, Herbert, 'Descriptions of New Species of Brachiopods and Molluscs from the Millstone Grit and Lower Coal Measures of Lancashire,' *Mem. Manchester Lit. and Phil. Soc.*, vol. 41, 1896, No. 6.

Manchester, becomes increasingly difficult of interpretation as it is followed west. In this direction marine bands appear on new horizons, the fresh-water faunas become considerably richer and more numerous, and the sandstones show an entirely different development. This extreme lateral variation in combination with want of exposures over large areas, makes identification of horizons exceedingly difficult. It is impossible within the limits of the present paper to give the arguments on which correlations can be based. Palaeontology affords only a very limited amount of help in this matter. The occurrence of two fossil-bands over the Six Inch Mine, the upper marine and the lower with *A. bellula,* makes the identification of this seam a fairly certain matter. Moreover the Arley Mine at the top of the succession is recognisable partly by associated fossil beds and partly through its position above the Old Lawrence Rock. The fresh-water fauna between the Six Inch Mine Marine Band and the Upper Mountain Mine in the west has the same forms as that between the Bassy and Lower Mountain Mines in the east, but is much more strongly developed on a greater number of horizons. The Lower Mountain Mine of the West has been identified by the mining community as equivalent to that of Rossendale, no doubt largely on account of its coking qualities, but its roof contains an abundant fauna of *Carbonicola,* which is absent or only locally present in the East. Gerrard's Marine Band has been found only in the West. Recent work by Mr. Chalmers, now in the press, seems to indicate that in good collections it is possible to distinguish the goniatite fauna obtainable from the Upper Foot Mine and Tonge's Marine Band in the West, but the latter is very thin in the East and does not yield identifiable material. The complete dissimilarity between the lower part of the Lower Coal Measures in these two areas is brought out in Plate II. The successions are not comparable in detail, yet Mr. L. H. Tonks' stratigraphical work seems to indicate that they are equivalent. He concludes that the Ganister Rock below the Lower Mountain Mine, the Woodhead Hill Rock below the Bassy Mine and the Ousel Nest Grit have combined to form the Harrock Hill Grit in the West, thus displacing the Lower Foot and Bassy Mines and their faunas, and that at the same time new fossil horizons have developed above and below.

The Fresh-water Fauna of the Lower Coal Measures

As regards subdivision on a faunal basis it is unfortunate that *A. lenisulcata,* which has been selected by Trueman as the zone-form of the lower part of the succession in Yorkshire, has not been proved to be present in Lancashire. Stratigraphical relations make it clear that strata equivalent to the Lenisulcata Zone are present, but the only Anthracomyas are *A. bellula* Bolton and *A. prisca* Trueman. *A. lenisulcata* is closely related to the first of these.

A. bellula, which occurs above the Six Inch Mine at the base of the Lower Coal Measures, is a survival from the Millstone Grit,

and having, as far as is known, a limited range, is a useful zonal form. As Bolton's description of this species[1] is inadequate for modern needs it is redescribed and refigured below. In conformity with former procedure in similar cases it is now proposed to establish the Bellula Subzone, within the less closely defined zone of *A. lenisulcata*.[2] This subzone includes, in Lancashire, the beds between the Upper Haslingden Flags and the Six Inch Mine Marine Band.

It is tempting to establish higher subzones on the basis of the species of *Anthracomya* that are present, such as for instance *A. prisca* Trueman, but they are so extremely rare in Lancashire as to make this course undesirable. About ten feet above the Six Inch Mine Marine Band the character of the fauna changes and Carbonicolas are dominant in all fresh-water beds up to the Upper Mountain Mine. This *Carbonicola* fauna presents exceptional difficulties in its extreme variability. It is possible that there is not a single shell in the series which is not a variant from one of two species. The variety of form is nevertheless so great that from the more productive beds it is possible to obtain specimens which, considered individually or in small groups, might be taken to indicate an horizon in the Middle Coal Measures. Considered as a whole, however, and having regard to the relative abundance of forms and their succession or rather want of definite succession in the series, any error of the kind is avoidable, provided exposure is such as to guarantee an ample supply of material. Nevertheless common forms hitherto justifiably regarded as indicating beds at least as high as the Modiolaris Zone, such, for instance, as *C. aquilna* (J. de C. Sow.), *C. phrygiana* Wright, *C. retrotracta* Wright, *C. concinna* Wright, *C. acutella* Wright, *A. richfordi* Wright, *A. modiolaris* (J. de C. Sow.), and *A. pulchra* Hind, are simulated with sufficient frequency to deceive, unless a comprehensive survey of the whole fauna is taken. Of course it is unlikely that these shells have any close genetic connexion with those from higher levels which they resemble, but it is doing no service to stratigraphy to refuse to face the fact that error is possible unless conditions of exposure are good, or geological considerations confine the range of possible horizons within a thousand feet or so.

In the case of the beds between the Bassy and Lower Mountain Mines in the neighbourhood of St. Helens and also at Feniscowles near Blackburn, where the Harrock Hill Grit is not developed as in other parts of west Lancashire, ample collections make possible a study of variation, and two forms seem to represent norms from which the whole series may be derived. These have not been figured previously and formal descriptions are incorporated below under the names *C. protea* and *C. fallax*. They are both common forms and consequently suitable for use in a zonal scheme. For

[1] Bolton, H., *op. cit.*

[2] Trueman, A. E., 'Some new Carboniferous Lamellibranchs,' *Ann. Mag. Nat. Hist.*, Ser. 10, vol. iv, 1929, p. 94; A. E. Trueman and W. D. Ware, 'Additions to the Fauna of the Coal Measures of South Wales,' *Proc. South Wales Inst. of Engineers*, vol. 48, 1932, p. 67.

this purpose *C. fallax* is preferable, being if anything the commoner of the two, and being capable of simple definition as having the form of the well known *C. aquilina* but being distinguishable from it by the fact that the lines of growth show little or no tilting over the greater part of the shell. In the rare cases where noticeable tilting is developed the resulting form is, as far as can at present be seen, indistinguishable from *C. aquilina* of the Modiolaris Zone.

Variation in the direction of increase in height combined with arching of the posterior umbonal slope, comparable with the variation of *C. aquilina* which produces *C. phrygiana,* also takes place, the resulting form being apparently *C. sulcata* (Brown), which is distinguished from *C. phrygiana* by the same absence or reduction of tilting of the lines of growth as distinguishes *C. fallax* from *C. aquilina.* It is fairly common. Other variants are numerous and are cited below in the account of the faunas of the various horizons.

Of the variants of *C. protea,* two, namely *C. recta* Trueman and *C. obliqua* sp. nov., are noteworthy. *C. recta* is especially abundant above the Lower Mountain Mine while the maximum development of *C. obliqua* appears to occur higher up, in the beds below the Upper Mountain Mine. A description of the latter species is incorporated below.

Above the Upper Mountain Mine are some 600 ft. of strata which have up to the present yielded no fresh-water fauna. As *C. fallax* does not recur above these beds, *i.e.* in the upper portion of the Lower Coal Measures, we may for the time being take this coal seam as the upper limit of the Fallax Subzone. The beds above the barren belt fall in the Ovalis Zone, the lowest of the fossiliferous horizons between the Old Lawrence Rock and the Arley Mine yielding this form and others allied to it. The Ovalis Zone in Lancashire thus embraces some 200 ft. of the Lower Coal Measures as well as the lower portion of the Middle Coal Measures. The Ovalis maximum probably occurs at the base of the zone. Above the Arley Mine it is rare, and *C. pseudorobusta* Trueman, which does not appear below this seam, is dominant.

The above constitute the outstanding characters of the succession of Lower Coal Measure fresh-water faunas in Lancashire. It remains to give formal descriptions of certain species and list the forms found on the various horizons.

Description of Species

Anthracomya bellula Bolton.

Fig. 1.

Herbert Bolton : 1896 : *Memoirs of the Manchester Literary and Philosophical Society,* Vol. 41, Part 6, p. 4, and Plate V, Fig. 5. Holotype in the Manchester Museum, labelled L.3419E.

coll. Dugdale, from shale under the Rough Rock, Bonfire Hill, Crawshawbooth, Lancashire. Topotype in the collection of the Geological Survey No. 53069, from the top of the Haslingden Flags, Bonfire Hill Quarry, Crawshawbooth, Rossendale, Lancashire.

Description:—A small shell definitely *Anthracomya*-form in outline, the maximum depth occurring one-third to one-quarter of

FIG. 1.—*Anthracomya bellula* Bolton. A. Holotype x 2. Manchester Museum Coll. L.3419 E. B. Topotype x 2. Geol. Surv. Coll. 53069.

the length from the posterior end. The ventral margin is gently curved, but from the point of maximum depth sweeps upwards to meet the posterior margin in a well rounded but very definite posterior-inferior angle. The hinge-line is very gently curved and passes through a broad and well-rounded angle into the curved posterior margin. The anterior umbonal slope is short and re-entrant, meeting the frontal margin in a slightly rounded angle of 90 or 100°. The anterior end of the shell is small, occupying about one-fifth of the length. The carinal ridge, if any, is very slight. The angle α between the hinge-line and a line from the umbo to the posterior-inferior angle is 15-20°. The angle β between the hinge-line and the posterior margin is difficult to estimate because of the curvature of the latter, but is very large, at least 150°. The maximum growth is postero-ventral so that the early lines of growth are definitely tilted.

Dimensions: l=14 mm. h=37.5%. t=?%. a=17.9%.

Notes:—Bolton's figure fails to bring out the *Anthracomya*-like character of the shell, which he recognised in his naming. In the left valve, which is the better exposed, the figure shows the maximum depth as about midway along the length of the shell. The right valve is rolled over vertically in the shale and the ventral margin is partly concealed. The posterior-superior angle is better exposed than that of the left valve, and the hinge-line is seen to be slightly curved and deflected towards the inferior margin before reaching the posterior-superior angle.

A. lenisulcata Trueman bears a distinct resemblance to this species, to which Trueman supposes it may be related. The main points of resemblance are the wide angle β and the position of maximum depth. The angle β is, however, less rounded off and the hinge-line is straighter. The lower border is also slightly inflected instead of being gently convex as in *A. bellula*. It is

just possible that the differences cited may, on examination of a further range of specimens, not prove to have specific value. If so, the name *A. bellula* has precedence.

The range of *A. bellula* is distinctly limited in Lancashire, being confined to the uppermost beds of the Millstone Grit Series, above the Haslingden Flags and the bottom few feet of the Lower Coal Measures immediately above the Six Inch Mine.

Carbonicola fallax sp. nov.

Fig. 2.

Holotype 53002 A. Paratype 53002 B. Both in the Geological Survey Collections.

Locality :—On south bank of River Darwen, 360 yds. N.E. of Emmanuel Church, Feniscowles, 1″ 75, 6″ Lancs. 70. N.W.

Description :—An elongated *Carbonicola* of small to medium size with a well developed posterior truncation. The long and fairly straight postero-dorsal slope makes a small angle with the ventral margin and passes through a rounded angle of 130-140° into the gently curved posterior margin. The well-rounded postero-ventral angle is about 50-60° and a broad rib or carina, varying considerably in prominence descends obliquely towards it from the umbo. The lower margin is very gently curved and sweeps up from a point a little behind the umbo into the margin of the short frontal lobe, which turns with varying angulation of approximately 90° into the short but deeply re-entrant anterior umbonal slope. The lines of growth are normally parallel to the ventral margin.

A

B

FIG. 2.—*Carbonicola fallax* sp. nov. A. Holotype. B. Paratype. Geol. Surv. Coll. 53002 A. and B.

Dimensions : Holotype l=28 mm. h=46½%. t=25 ?%. a=25%.
Paratype l=23 mm. h=50%. t=32 ?%. a=26%.

Notes :—This species has a distinct resemblance to *C. aquilina* and *C. concinna* of the Modiolaris Zone. From the former it is distinguished by the much less tilted lines of growth and the absence of tilting of the umbones, from the latter by the lower and less rounded frontal lobe and the comparative straightness of the posterior umbonal slope. Variants, however, simulate both forms.

The study of a large number of specimens of this species group shows that it is liable to an exceptional degree of variation. The description given above applies only to the norm, which, however, is the commonest form in the beds in which it occurs.

Horizon and range :—The type specimens are from beds between the Bassy and Lower Mountain Mines. The species, however, ranges throughout the lower half of the Lower Coal

Measures, from above the Six Inch Mine Marine Band to below the Upper Mountain Mine.

Carbonicola protea sp. nov.

Fig. 3.

Holotype 53003 A. Paratypes 53003 B, 53070, 53071.

Locality :—On south bank of River Darwen, 360 yds. N.E. of Emmanuel Church, Feniscowles 1″ 75, 6″ Lancs. 70 N.W.

Description :—Shell fairly large, oblong in general shape, with a deep roundly truncate posterior end. The posterior umbonal slope, which is straight or slightly curved and makes a small angle with the ventral margin, curves more abruptly, or in other words

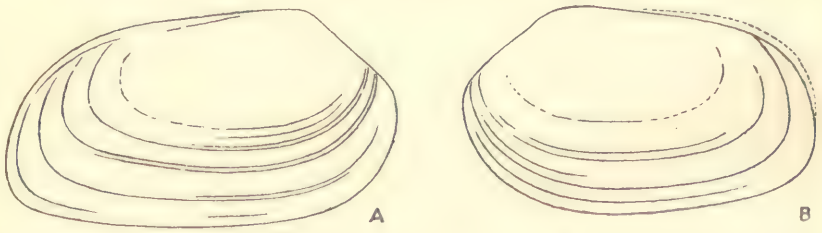

FIG. 3.—*Carbonicola protea* sp. nov. A. Holotype. B. Paratype. Geol. Surv. Coll. 53003 and 53071.

is slightly angulated where it passes into the curved posterior margin. The angulation where the latter meets the ventral margin is more sudden but still well rounded, the indefinite angle produced varying round 80 or 90°. The lower margin is gently but definitely curved and sweeps upward from a point below the umbones into the anterior margin. The anterior umbonal slope is of moderate length, and not very re-entrant. The early lines of growth sometimes make a small angle with the later, so that the umbo, which is by no means prominent is tilted slightly forward.

Dimensions of Holotype : l = 50 mm. h = 57%. t = ?%. a = 20-22%.

Notes :—Variation in different directions causes this species to approach *C. communis* Davies and Trueman, *C. recta* Trueman, *C. obliqua* sp. nov., *C. ovalis* (Martin), and *C. rhomboidalis* Hind. Hence its name.

Horizon and Range :—The type specimens are from beds between the Bassy and Lower Mountain Mines, where they accompany *C. fallax*. The species, however, is also abundant in the roof of the Lower Mountain Mine, where its supposed variant *C. recta* is common.

Carbonicola obliqua sp. nov.

Fig. 4.

Holotype 53004. Paratypes 53073, 53074.

Locality : Twenty to thirty feet below the Rambler or Upper Mountain Mine in Ravenhead Brickworks Quarry, Holland Moor, 1 mile west of Upholland. 1″ 84, 6″ Lancs. 93 S.W.

Description :—An elongated shell with marked truncation and fairly prominent umbones, oval in section, and with a full, rounded and fairly high anterior lobe. The dorsal margin, above which

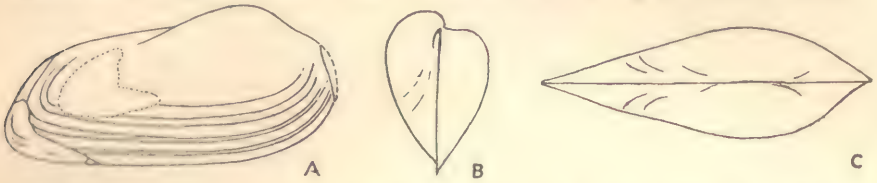

Fig. 4.—*Carbonicola obliqua* sp. nov. Holotype. A. Right valve. B. and C. Front and top views. Geol. Surv. Coll. 53004.

the umbones rise slightly, is nearly straight and makes a rounded angle of about 130° with the slightly curved posterior margin. The ventral margin is also nearly straight, except where it curves upward from beneath the umbones into the anterior margin. At the back it curves suddenly through a rounded angle of about 60° into the posterior margin. The shell is thus obliquely truncated. The lines of growth being approximately parallel to the margins, the shell when partially grown has roughly the same shape except that the posterior-inferior angle is greater in the early stages and the truncation less oblique. The greatest thickness from valve to valve is one-third of the length and occurs a little behind the umbones and two-thirds of the height from the ventral margin.

Dimensions of holotype : l = 44 mm. h = 47%. t = 33%. a = 27%.

Notes :—The holotype has been crushed obliquely so that the valves are sheared on one another. The specimen He. 4098 described as *C.* aff. *communis* Davies and Trueman on p. 134 of ' The Geology of Manchester ' (*Mem. Geol. Surv.*), is nearer this species than any other, and is for present purposes included in it.

This is probably a variant of *C. protea* in the beds above the Bassy Mine, but it becomes dominant at higher horizons and is then apparently a true species.

It is distinguished from *C. protea* by the greater elongation, the more oblique truncation and the prominence of the umbones, from *C. recta* by the oblique truncation, from *C. subconstricta* (J. Sowerby) by the greater length of the posterior margin or truncation and from *C. binneyi* Wright by the comparative straightness of the lower margin, the prominence of the umbones and the shorter anterior end.

Range.—The range appears to be different from that of either *C. protea* or *C. recta*, for while it appears first as a variant with *C. protea* above the Bassy Mine, it occurs with both *C. recta* and *C. protea* in the roof of the Lower Mountain Mine and ultimately becomes dominant in the beds below the Upper Mountain Mine. It is also found in the beds below the Arley Mine.

Carbonicola haberghamensis sp. nov.

Fig. 5.

Holotype 53005. Paratype 53006.

Locality: New Barn Clough, Habergham Eaves, Burnley; section 250 yds. N.W. of Micklehurst Farm. 1″ 76, 6″ Lancs. 64 S.W.

Description: Shell large, oblong in general shape, the casts of the umbones fairly prominent rising above the straight 'hinge-line.' This latter is of variable length and is cut off at a rounded

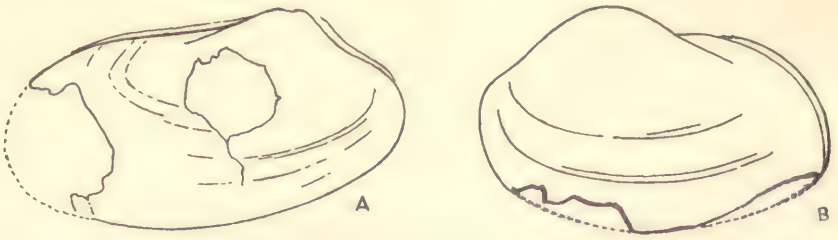

FIG. 5.—*Carbonicola haberghamensis* sp. nov. A. Holotype. B. Paratype. Geol. Surv. Coll. 53005, 53006.

angle of about 150° by the well curved, deep truncation or posterior margin. As the lower border of the shell is also well curved it is difficult to give any figure for the value of the posterior-inferior angle, a difficulty which is increased by imperfection of the types. The general trend of the well curved lower margin is parallel to the hinge line. It sweeps up from a point beneath or behind the umbo into the rounded front margin, which is cut off at about 120° by the long, slightly re-entrant anterior umbonal slope. The anterior lobe is thus well below the level of the hinge-line.

Dimensions: Holotype l=50 mm. h=52%. t=30%. a=24%.
Paratype l=46 mm. h=63%. t=30%. a=38%.

Notes: This very distinct form is probably a variant of *C. protea* and would perhaps hardly be worthy of specific rank were it possible to describe it by comparing it with any named species or variety. The only figured species at all resembling it is *C. bipennis* (Brown) from the Low Moor Ironstones, which are in the

Lower Coal Measures of Yorkshire, but being about 150 ft. above the Better Bed are probably in strata equivalent to the Middle Coal Measures of Lancashire. The posterior margin in the latter is less curved and the umbones do not rise above the hinge-line.

C. haberghamensis is on a par with many of the named species of *Carbonicola* which are extreme forms produced by variation from a less distinctive norm. These are, however, often highly characteristic of horizons, and a nomenclature which stresses their occurrence is of zonal value. It has been found to occur on the same horizon in areas far distant from the type locality, and being distinctive in shape and readily recognisable is more valuable for stratigraphical purposes than the generalised and easily simulated *C. protea*. It appears to be characteristic of the beds between the Bassy and Lower Foot Mines.

Carbonicola limax sp. nov.

Fig. 6A.

Holotype 53007.

Locality : Holotype : On E. bank of stream on hillside, 1,160 yds. E.9°.S. of Dimple and $\frac{1}{8}$ mile N.N.E. of Parish Church, Egerton, 1″ 76, 6″ Lancs. 79 S.W., from above the Lower Foot Mine.

Description : An elongated shell resembling *C. fallax* except that the posterior umbonal slope forms an arch rising to a higher level than the umbo which is thus appreciably tilted forward. The later lines of growth over the greater part of the shell are also generally inclined to the lower margin. The lower margin is straight and the curvature of the posterior umbonal slope causes it to run continuously into the posterior margin so that posterior-superior angulation is wanting and the shell is thus untruncated. The maximum height is about midway along the length of the shell, well behind the umbones.

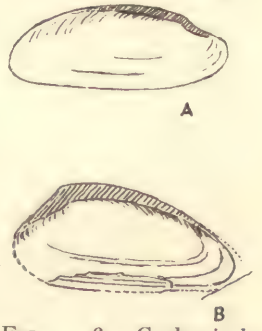

FIG. 6.—*Carbonicola limax* sp. nov. A. Holotype. B. An allied form showing thickness of the shell about the umbo. Geol. Surv. Coll. 53007, 53072.

Dimensions : Holotype l = 28 mm. h = 46.5%. t = 21.5 ?%. a = 20%

Horizon and Range : Known in the Lower Coal Measures above the Lower Foot Mine and below the Harrock Hill Grit, but being merely a humpbacked variant of *C. fallax* and *C. aquilina* it will probably be found to have a wider range. Specimens intermediate between *C. limax* and *C. phrygiana* are common below the Upper Mountain Mine of Upholland.

Notes:—This form is probably allied to *C. sulcata* (Brown) from which it can only be separated by its lesser height and elongated form. It resembles *C. aquilinoides* Tchernyshev[1] from the Modiolaris Zone of the Donetz Basin and if it should prove to be identical the latter name has precedence.

Description of Horizons

Six Inch Mine, Subzone of A. bellula:—In the Rossendale area the Six Inch Mine Marine Band occurs directly over the Coal. At Darwen and Blackburn however it is separated from it by an Anthracomya bed, and the occurrence of the same bed at Micklehurst Wood, 1 mile north-east of Parbold seems to suggest that this variation in the succession is characteristic of the western part of the coalfield. The six-inch belt of mudstone separating the Anthracomya bed from the marine band yields *Lingula* and fish scales.

The Anthracomyas of this horizon are in the main *A. bellula* Bolton, though some have greater depth than the type. There is however, a second less common form, exemplified by Hs. 1554 and De 2177, which resembles the specimen figured by Hind[2] from Bilboa, Queen's County, Ireland. This has parallel hinge and lower margin and frequently a better defined and smaller posterior-superior angle. It is probably the same shell as that mentioned by Trueman as accompanying *A. lenisulcata* above the Pot Clay Coal of Yorkshire.[3]

The best exposure of this horizon is that above the old bridge in Green Lowe Clough, 300 yds. west-south-west of Cadshaw and 2½ miles south of Darwen Station. Here the shells are larger than usual and display a good deal of variation, especially in the curvature of the lower margin. A few of them have the greatest depth at the umbo and are definitely *Carbonicola*-like, a further example of the occasional difficulty experienced in separating the two genera. The ostracod, *Jonesina arcuata* (Bean) also occurs in this bed.

The Beds beneath the Harrock Hill Grit:—In the neighbourhood of Parbold, where the Harrock Hill Grit is developed, the beds beneath, extending down to the Six Inch Mine Marine Band, are highly fossiliferous, whereas what appear to be the equivalent beds in the east are as far as is known quite barren. Collections have been made from the following localities in the Parbold area.

4. Parbold Quarries, cutting, 300 yds. north-north-west of Gillibrand House, 10 ft. below the Harrock Hill Grit.

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[1] Tchernyshev, B., '*Carbonicola, Anthracomya* and *Naiadites* of the Donetz Basin,' *Trans. Geol. and Prospecting Service of U.S.S.R.*, Fascicle 72, 1931, plate 2, fig. 30.
[2] Hind, W., 'A Monograph on *Carbonicola, Anthracomya* and *Naiadites*': *Palaeontographical Soc.*, 1896, pl. xvii, fig. 6.
[3] Trueman, A. E., *op. cit.*, *Ann. Mag. Nat. Hist.*, Ser. 10, vol. iv, 1929, p. 95.

3. Lane on north-east side of Harrock Hill, 250 yds. north-north-west of Dwerryhouse, 25 ft. below the Harrock Hill Grit.
2. Section in stream, 300 yds. north-west of Harrock Hall, below 3.
1. Crop workings on Harrock Hill, 400 yds. north-west of Dwerryhouse, 10 ft. above the Six Inch Mine.

Unfortunately the material from these localities is very poorly preserved and only small collections are available in the case of the three lowest. No. 1, the lowest horizon of all, yielded *C. recta* Trueman and a few obscure shells regarding which all that can be stated is that they have curved lower margins, and are therefore hardly referable to that species. The material obtained from horizon 2 is still more unsatisfactory. It includes shells referable to *C. fallax* and possibly *C. sulcata* (Brown). Horizon 3 is a little better. It yields *C. fallax* and variants approaching *C. elliptica* Wright, and also *C. recta* and *C.* cf. *protea*. From horizon 4 a fairly extensive collection is available, but the material is still poorly preserved. The commonest form is *C. fallax*. Present also are *C. limax*, *C.* cf. *sulcata* (Brown), *C.* cf. *pyramidata* (Brown), *C.* cf. *faba* Wright, *C.* cf. *recta* Trueman, *C.* cf. *transversa* (Brown), and some obscure *Anthracomya*-like forms. All these are probably variants from *C. fallax*.

The Beds above the Bassy Mine :—Outside the Parbold area the lowest known *Carbonicola*-bearing horizon in the Lower Coal Measures is that above the Bassy Mine. It is supposed that at Parbold these fossil-beds are replaced by the Harrock Hill Grit. The Carbonicolas occur on a number of horizons from the Bassy Mine to the Lower Foot Mine. Excellent material has been obtained from two localities in the west of the field, one at Windle north of St. Helens and the other at Feniscowles west of Blackburn, and a more than usually complete study of the fauna has been made possible. The two commonest forms are *C. fallax* and *C. protea*, described above. By variation from these forms the following species are simulated.

(1) From *C. fallax* :—*C. sulcata*, *C. limax*, *C. phrygiana*, *C. aquilina*, *C. concinna*, *C.* cf. *acutella*, *C.* cf. *carissima* Wright, *C.* cf. *elliptica*, *C. faba*, *C.* cf. *venusta* Dav. and Tru., *C.* cf. *pyramidata* (Brown), *A.* cf. *richfordi* Wright, *A.* cf. *modiolaris*, *A.* cf. *librata* Wright, and *Anthracomya sp.*

(2) From *C. protea* :—*C.* cf. *recta*, *C. obliqua*, *C.* cf. *communis* Davies and Trueman, *C.* cf. *rhomboidalis* Hind, *C.* cf. *ovalis* (Martin), *C.* cf. *acuta* (J. Sow.), *C.* cf. *haberghamensis*, *C.* cf. *retrotracta*, *C.* cf. *turgida* (Brown), *C.* cf. *elliptica* and *Carbonicola sp. nov.*

Lower Foot Mine :—The fauna in the roof of the Lower Foot Mine is known only in the eastern portion of the Lancashire coal-field and that rather imperfectly owing to the poor state of preserva-

tion of the material. It yields undoubted *C. recta* and *C. fallax*, the latter accompanied by several variants with curved lower margin.

Lower Mountain Mine:—In the east of the coalfield the Lower Mountain Mine is overlain by black shales with fish remains and this relatively barren roof persists as far west as Wigan. In the Upholland area however, the coal to which this name is given,

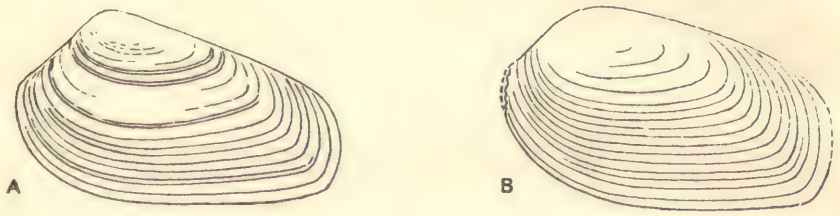


FIG. 7.—*Carbonicola recta* Trueman. From the roof of the Lower Mountain Mine. Tip-heaps of Pimbo Lane Colliery, Upholland Colliery and Byeproducts Co., 280 yds. E.S.E. of Upholland Station, 1-inch Sheet 84, 6-inch Sheet Lancashire 93 S.W. A. A specimen closely resembling the type, Geol. Surv. Coll. 53008. B. A deeper form showing an approach to *Carbonicola protea*. Geol. Surv. Coll. 53009.

and probably correctly, has a roof with abundant well-preserved Carbonicolas. The dominant form is *C. recta* Trueman. *C. protea*, which is the norm in the beds above the Bassy Mine is however present, and also *C. obliqua*, which attains its maximum at higher levels. A variant of *C. protea* closely simulates *C. rhomboidalis* Hind. *C. fallax* also occurs, along with variants approaching *C. aquilina* and *C. elliptica*.

Beds below the Upper Mountain Mine:—In the Upholland Area a well preserved fauna occurs below the Rambler or Upper Mountain Mine. The Ravenhead Brickworks Quarry, Holland Moor, 1 mile west of Upholland, shows the following sequence:—

	Ft.
Coal and Fireclay (Rambler Mine)	
Mudstone	20
Gerrard's Marine Band	
Mudstone with *Carbonicola*, Bed B	11
Fireclay, sandstone and mudstone	20
Mudstone with *Carbonicola*, Bed A	12

In bed A the commonest species is *C. fallax*, but *C. aquilina* is frequent. *C.* aff. *limax*, *C. sulcata* and *C. phrygiana* are also common along with forms intermediate between them. There are also shells resembling *C. communis* Dav. and Tru. *A. minima* and *Spirorbis* are present and two specimens of an *Anthracomya*-like form which however may be a variant of *C. fallax*.

In bed B, *C. obliqua* is completely dominant, although an occasional shell may show an approach to *C. subconstricta* or *C. recta*. There are also some small shells resembling young *Naiadites*.

Although bed A is the lowest fossiliferous horizon seen in the Ravenhead Quarry, a still lower bed of the series between the Foot and Upper Mountain Mines has been seen at Middle Wood, 1,980 yds. west-south-west of Appley Bridge Station. It yielded poorly preserved specimens of *C. fallax* and its variants, along with *C.* cf. *pyramidata* (Brown), *A. minima*? and *Jonesina arcuata*.

Highest Beds of the Lower Coal Measures:—The Upper Mountain and Cannel Mines are succeeded throughout the coalfield by a series of mudstones and sandstones some 700 ft. thick, from which no fossils have up to the present been obtained. The uppermost sandstone of the Series is known as the Old Lawrence Rock and above it Carbonicolas again make their appearance. In some old brick-pits above the Bolton Road at Horwich the mudstones contain ironstones in which are found *C. ovalis* (Martin), *C. centralis* Hind and allied forms some of which show a slight posterior truncation and are not therefore true *C. ovalis*. Obscure specimens suggestive of *C. subconstricta* and *C. communis* are also found along with *Naiadites* and *Spirorbis*. A similar fauna is found much further west to the south-east of Rainford in beds which mapping would indicate to be on the same horizon, that is, some 150-200 ft. below the Arley Mine. This is the beginning of the Ovalis Zone and possibly the maximum of *C. ovalis*.

Higher up in these beds at a level about 60 ft. below the Arley Mine is a much more strongly developed fossil band in which *C. subconstricta* is the dominant species. Specimens which suggest *C. robusta* (J. de C. Sowerby) also occur but *C. pseudorobusta* Trueman (=*C. robusta* Hind *pars*) does not make its appearance below the Arley Mine.The fauna also includes *C.obliqua*,[1] *C.* cf. *ovalis* (a short form), *C. sulcata, Naiadites, A. minima, Jonesina arcuata,* and *Spirorbis*. The absence of any form resembling the ubiquitous *C. fallax* of the lower measures is very noticeable. This has not yet been found above the Upper Mountain Mine. On the other hand *C. obliqua* has survived but is rare.

There remains one bed which is possibly higher than the last-mentioned. It occurs in Ravenhead Colliery, St. Helens, about 20 ft. below the Little Delf or Arley Mine, and also at Holland Colliery. The fauna consists in the main of small shells with characters suggesting their relationship to *C. subconstricta, C. sulcata* and *C. phrygiana* but it is difficult to say definitely that any of these species are present. A single imperfect specimen of a large shell with radial striation suggests *C. decorata* Trueman but the posterior end is lost. In so far as it can be seen the outline is like that of *C. robusta* from the bed below.

Summary of Results

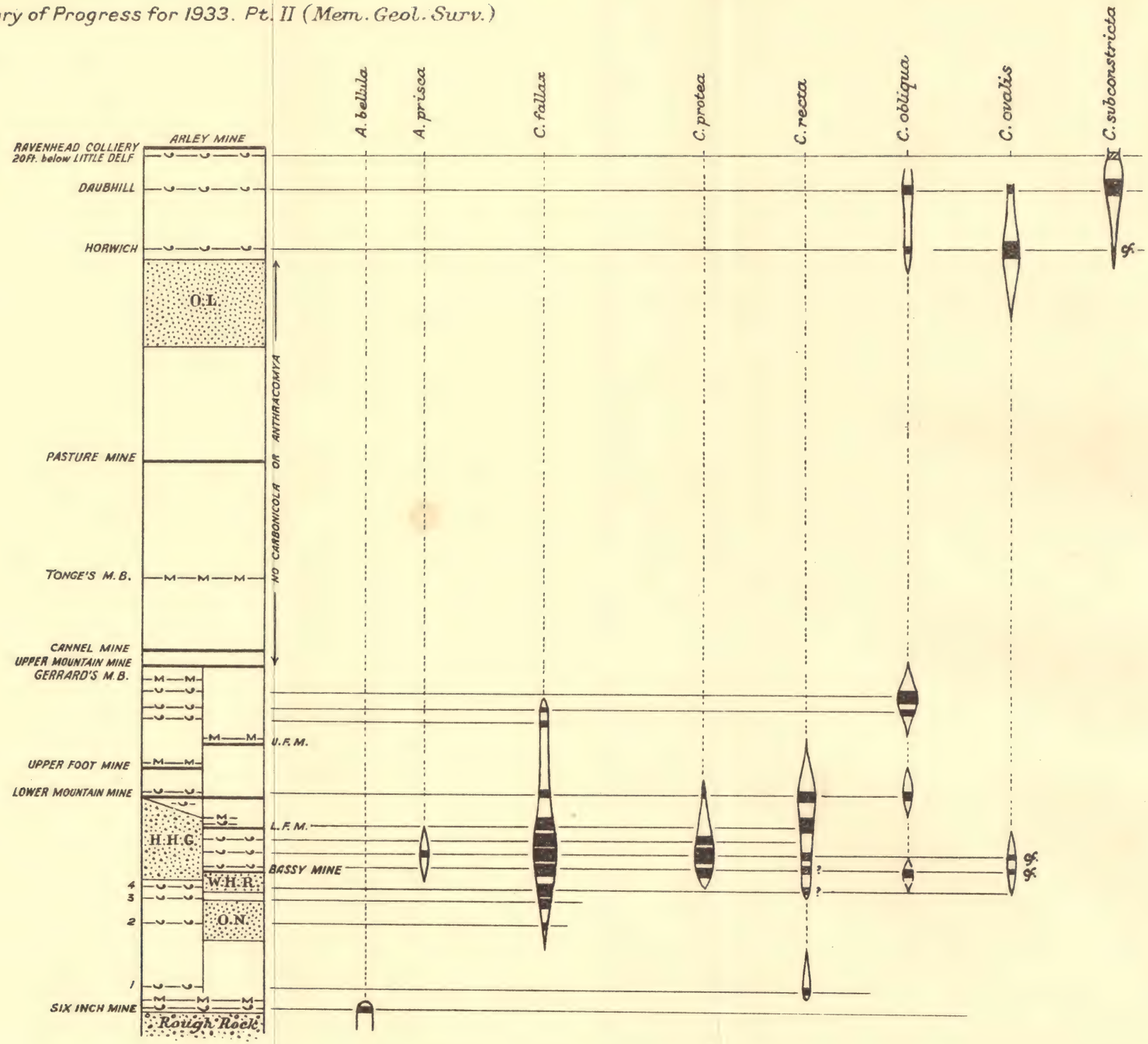
The fresh water molluscs of the Lower Coal Measures, which appear utterly disconcerting at first contact on account of the

[1] Figured in the Manchester Memoir, text-fig. 46 B, p. 134, as *C.* aff. *communis*.

extreme variability of some of the forms and the manner in which they simulate those on higher horizons, can be reduced on close analysis to a fair degree of simplicity, and provide a certain amount of useful zonal subdivision, which however needs good exposure and plentiful material for its application. The bottom of the Lower Coal Measures clearly lies within Trueman's Zone of *A. lenisulcata,* the top in that of *C. ovalis.* The line of demarcation is unknown but probably lies in the barren strata above the Upper Mountain Mine, since Trueman records *A. lenisulcata* at much higher levels than its close relative *A. bellula* occupies in Lancashire.

Proceeding to closer subdivision the Subzone of *A. bellula* is well marked at the base, embracing the uppermost beds of the Millstone Grit and the bottom foot or two of the Lower Coal Measures up to the Six Inch Mine Marine Band. Next comes the subzone of *C. fallax* extending from the Six Inch Mine Marine Band up to the barren strata above the Upper Mountain Mine. This has three well-marked maxima, that of *C. protea* above the Bassy Mine, that of *C. recta* above the Lower Mountain Mine and that of *C. obliqua* below the Upper Mountain Mine. Then comes the Barren Belt, and above it about 200 ft. of strata, with a maximum of *C. ovalis* at the base, introducing the Ovalis Zone, and a maximum of *C. subconstricta* about 60 ft. below the Arley Mine, which begins the Middle Coal Measures.

This apparently simple sequence, which is exhibited diagrammatically in Plate II, is however masked by the exceptional variation displayed by the two species *C. fallax* and *C. protea,* which simulate a great number of forms hitherto considered to be characteristic of higher beds. It is clear that extreme caution is necessary in fixing the horizons of Coal Measures by their fauna alone, and that serious error may result unless exposures are considerable and collections large.



Range diagram of Significant species of Anthracomya and Carbonicola in the Lower Coal Measures of Lancashire. Vertical scale roughly 200 or 300 ft. to one inch according to locality.

Description of Plate II

Range-diagram of significant species of *Anthracomya* and *Carbonicola* in the Lower Coal Measures of Lancashire. M.B. = Marine Band, O.L. = Old Lawrence Rock, U.F.M. = Upper Foot Mine, L.F.M. = Lower Foot Mine, H.H.G. = Harrock Hill Grit, W.H.R. = Woodhead Hill Rock, O.N. = Ousel Nest Grit.

III.—VARIATION OF FRESH-WATER SHELLS IN THE LOWER COAL MEASURES OF LANCASHIRE

BY

W. B. WRIGHT, Sc.D.

Text-figures 1—14.

THE beds between the Bassy Mine and Lower Foot Mine in the Lower Coal Measures of Lancashire appear on cursory examination to have an extraordinarily varied fauna of *Carbonicola* and *Anthracomya*, embracing forms indistinguishable from or closely simulating many species represented on higher horizons, and up to the present regarded with some reason as characteristic of these horizons. Careful analysis of extensive collections from these beds seems, however, to show that most of the forms are merely variants from two species, which are very abundant, and appear to function as norms. These species are both new, and are described in this volume (pp. 13, 14) under the names *C. protea* and *C. fallax*. They are apparently not quite independent of one another, the gap between them being bridged by the occurrence of rarer intermediate forms, so that the two together can be regarded as a sort of binary centre of variation. Variants from one of the species can in some cases be connected by intermediate forms with those from the other, and the same variant may thus be considered as derived from either.

In order to avoid much description an attempt is made in Fig. 1 to diagrammatise the variation observed. The use of specific names in this diagram merely indicates that the species cited is considered to be simulated with sufficient accuracy to mislead if taken apart from its associates. Possibly palaeontological practice would counsel the prefixing ' cf.' to all such names, since the forms thus indicated are not claimed to have any genetic connexion with those on higher horizons to which the names are properly applicable. The letters ' cf.,' which after all only mean ' compare,' are, however, reserved here for lesser degrees of approximation.

Such a diagram, however, conveys little impression of the gradualness of the transition from one extreme form to another. The different lines taken by the variation must for this purpose be taken one by one, and this is attempted in a series of figures, of which the letterpress is merely explanatory. The specimens selected for figuring are, where possible, gauged to show the gradualness of the transition from form to form. This is admittedly not so perfect in some cases as in others. It will be readily conceded that the extreme forms are quite distinct from one another, but it will also be found that the lines of demarcation between them are not easily drawn.

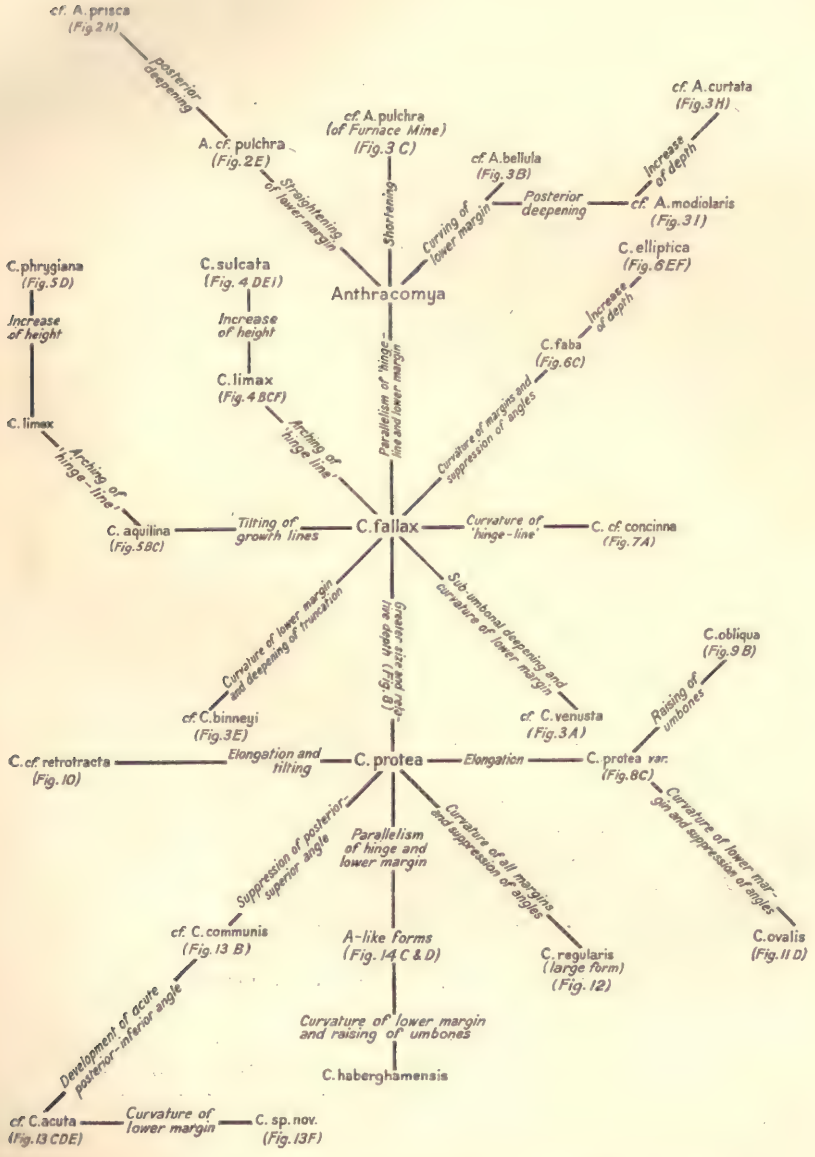

cf. A. prisca (Fig. 2 H)
Posterior deepening
A. cf. pulchra (Fig. 2 E)
Straightening of lower margin
cf. A. pulchra (of Furnace Mine) (Fig. 3 C)
Shortening
cf. A. bellula (Fig. 3 B)
Curving of lower margin
Posterior deepening
cf. A. modiolaris (Fig. 3 I)
Increase of depth
cf. A. curtata (Fig. 3 H)
C. phrygiana (Fig. 5 D)
Increase of height
C. limax
Arching of hinge-line
C. sulcata (Fig. 4 DEI)
Increase of height
C. limax (Fig. 4 BCF)
Arching of hinge line
Anthracomya
Parallelism of hinge-line and lower margin
C. elliptica (Fig. 6 EF)
Increase of depth
C. faba (Fig. 6 C)
Curvature of margins and suppression of angles
C. aquilina (Fig. 5 BC)
Tilting of growth lines
C. fallax
Curvature of 'hinge-line'
C. cf. concinna (Fig. 7 A)
Curvature of lower margin and deepening of truncation
Greater size and rib-like ridges (Fig. 8 D)
Sub-umbonal deepening and curvature of lower margin
cf. C. binneyi (Fig. 3 E)
cf. C. venusta (Fig. 3 A)
C. obliqua (Fig. 9 B)
Raising of umbones
C. cf. retrotracta (Fig. 10)
Elongation and tilting
C. protea
Elongation
C. protea var. (Fig. 8 C)
Curvature of lower margin and suppression of angles
Suppression of posterior-superior angle
Parallelism of hinge and lower margin
Curvature of all margins and suppression of angles
cf. C. communis (Fig. 13 B)
A-like forms (Fig. 14 C & D)
C. regularis (large form) (Fig. 12)
C. ovalis (Fig. 11 D)
Development of acute posterior-inferior angle
Curvature of lower margin and raising of umbones
C. haberghamensis
cf. C. acuta (Fig. 13 CDE)
Curvature of lower margin
C. sp. nov. (Fig. 13 F)

FIG. 1.—*Diagram showing variation in* C. fallax *and* C. protea.

Anthracomya-like Variants of Carbonicola fallax.—The ill-definition of the genera *Anthracomya* and *Carbonicola* is a standing difficulty in the palaeontology of the Coal Measures, a difficulty fully appreciated by Davies and Trueman in their 1927 paper.[1] In the beds above the Bassy Mine forms occur quite frequently which can be referred with equal reason to one genus or the other. Moreover they occur along with transitional forms linking them on the one hand with *C. fallax* and on the other with *Anthracomya*.

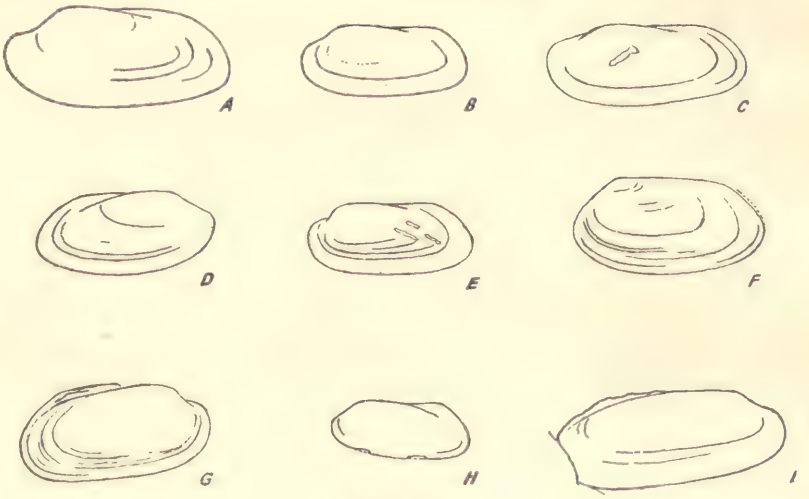


FIG. 2.

A. Dw 1650	*B.* Dw 1634B	*C.* Dw 1634A
D. Dw 1638A	*E.* Dw 1632A	*F.* Dw 1705B
G. De 1165	*H.* Dw 1706	*I.* Dw 1865

The series of shells shown in Fig. 2 can, for instance, be easily regarded as derived one from the other by slight variations, yet A is the norm of *Carbonicola fallax*. Forms B and C might reasonably be regarded as falling within that species, but very similar shells occurring with *A. bellula* Bolton above the Six Inch Mine and Pot Clay Coals are commonly regarded as Anthracomyas. E closely resembles *A. pulchra* Hind, G simulates *A. richfordi* Wright of the Modiolaris Zone, and H is possibly *A. prisca* Trueman. D and F have characters which recall those of the Anthracomyas of the Librata-group from the upper part of the Pulchra Zone. I of Fig. 2 might be regarded as intermediate in form between A and G, and K and L of Fig. 3 fall into the same series.

The remainder of the shells shown in Fig. 3 show more pronounced curvature of the lower margin than is displayed by the norm of *C. fallax*, and with the exception of A approximate in

[1] Davies, J. H. and A. E. Trueman, 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures,' *Quart. Journ. Geol. Soc.*, vol. 83, 1927, p. 220.

form to certain species of *Anthracomya* by having the maximum depth far back. B resembles *A. bellula* of the Six Inch Mine and D is a shortened form of the same variant. C is close to the variant of *A. pulchra* found in the Furnace Mine at the base of the Pulchra Zone in Lancashire.[1] E and F again show characters which suggest the Anthracomyas of the Librata-group from the upper part of the Pulchra Zone, but on the other hand this form is very similar to some of the shells included in the species *C. binneyi* Wright[2] of the Ovalis Zone. G, I and J are like *A. modiolaris* (J. de C. Sow.), especially I. In G and J the posterior-superior angle is too great for this species. H is an extreme variant in the same direction and may be compared with *A. curtata* (Brown).[3]

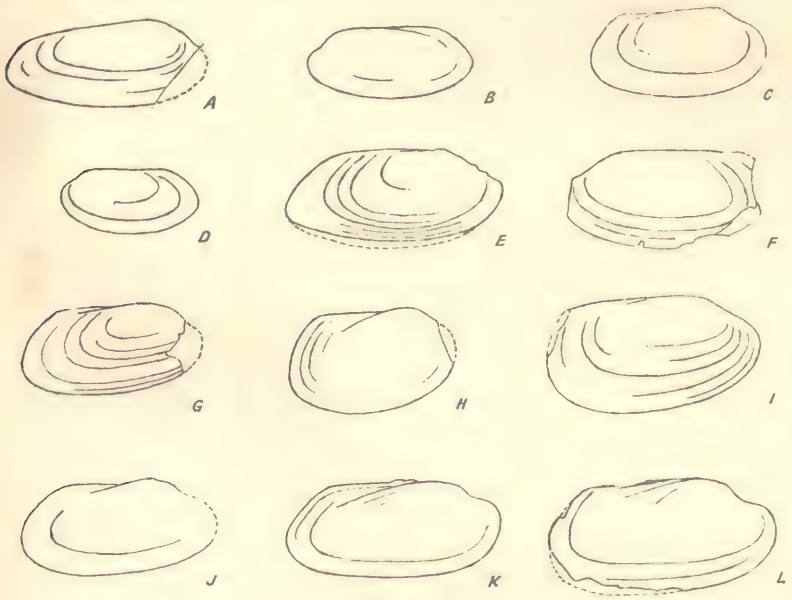


FIG. 3.

A. Dw 1609A *B.* Dw 1609B *C.* Dw 1629
D Dw 1662A *E. and F.* De 1215 *Right and Left Valves.*
G. De 1214 *Right Valve* *H.* Dw 1707 *Right Valve* *I.* De 1218
J. Dw 1626 *K.* De 1197 *L.* De 1198

Simulation of the Aquilina-Phrygiana Group.—The development of *C. phrygiana* Wright from *C. aquilina* (J. de C. Sow.) in the Modiolaris Zone has its analogue in the Lower Coal Measures in the development from *C. fallax* of similar forms with arched posterior umbonal slopes, but without any marked tilting of the lines of growth. Brown has described a similar shell from Whitehaven under the name *C. sulcata*, but its horizon is unknown. The shells with these characters from above the Bassy Mine are

[1] 'The Geology of Manchester' (*Mem. Geol. Surv.*), 1931, p. 145, fig. 55B.
[2] *Ibid.*, p. 135, fig. 47C.
[3] *Ibid.*, p. 138, fig. 49E.

not sufficiently different from Brown's species to justify a separate name, although a slight distinction might be found in the forward tilting of the umbo, some measure of which is always associated with arching of the posterior umbonal slope. This is shown in Brown's figure as very pronounced, whereas it is slight

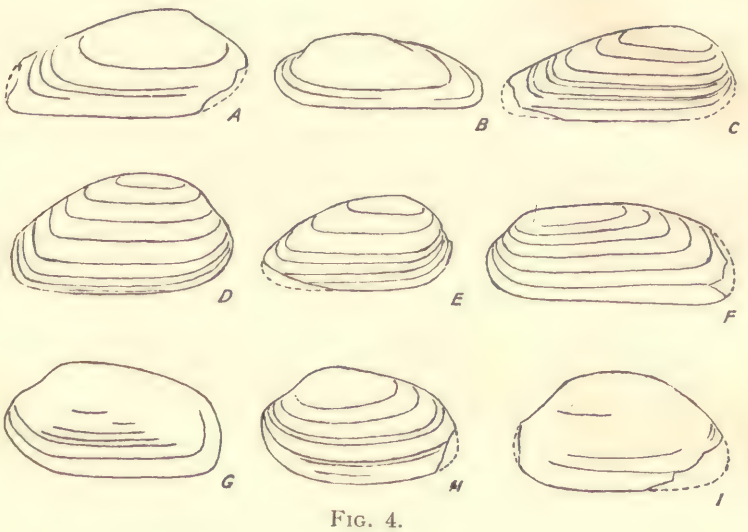


FIG. 4.

A. De 1196	*B*. De 1344	*C*. De 1328
D. De 1280	*E*. De 1331	*F*. De 1327
G. Dw 1703	*H*. Dw 1682	*I*. De 1183

in the otherwise similar shells of the Lower Coal Measures. In this connexion it has to be remembered that Brown's figures, the types of which are lost, give as a whole the impression of gross exaggeration in the drawing. No shell exactly comparable with the figure of *C. sulcata* has yet been found in the Coal Measures of Lancashire on any horizon high or low. Shells approaching it in character are, however, common in the Lower Coal Measures and correspondingly rare at higher levels. That they are variants from *C. fallax* will, I think, be apparent from Fig. 4 in which A is near the last-mentioned species, while C, D, E and I approach the form of *C. sulcata*. B and F resemble *C. limax* (see page 17) and H is rather abnormal. G approaches in form those specimens of *C. recta* Trueman from horizons above the Six Inch Mine.

The development of pronounced tilting and consequent production of forms indistinguishable from *C. aquilina* and *C. phrygiana* is rare in the Lower Coal Measures, but it does occur

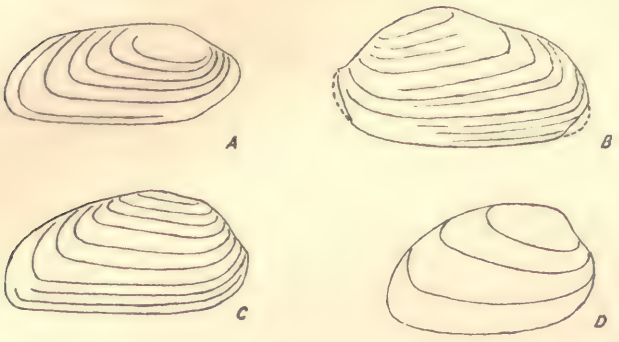


FIG. 5.

A. De 1285 *B*. De 1287
C. De 1329 *D*. De 1191A

and to some extent vitiates the utility of these species as zonal indices of beds above the lower portion of the Modiolaris Zone. In Fig. 5, A is the norm of *C. fallax*, figured here merely for purposes of comparison, B and C are *aquilina*-like forms, C being quite indistinguishable from *C. aquilina* of the Stubb's Mine in the upper part of the Modiolaris Zone,[1] while D has all the essential characters of *C. phrygiana*.[2]

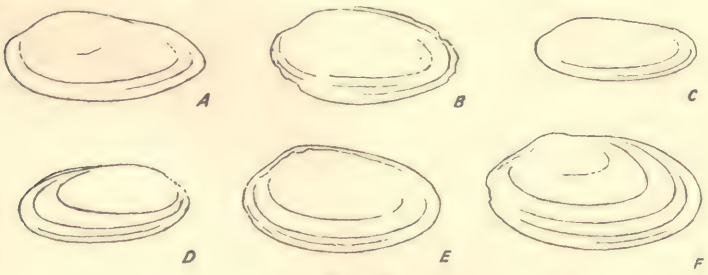


FIG. 6.

A. De 1148 *B*. De 1201 *C*. De 1302
D. De 1216 *E*. Dw 1646 *F*. De 1217

Simulation of the Elliptica-Faba Group.—Variation in the direction of reduced angularity is extremely common and requires little description. It is exemplified in Fig. 6. A is a variant of *C. fallax* not far removed from the norm except in the curvature of the lower margin. C shows also curvature of the posterior end or truncation, but there is still a slight suggestion of a postero-dorsal angle. This, however, has disappeared in D which is indistinguishable from *C. faba* Wright[3] of the passage beds between the Modiolaris and Pulchra Zones in Lancashire. Increasing relative depth produces forms such as B, E and F, which are

[1] See 'The Geology of Manchester' (*Mem. Geol. Surv.*), 1931, p. 142, fig. 53E.
[2] *Ibid.*, fig. 53F.
[3] *Ibid.*, p. 143, fig. 54.

very close to *C. elliptica*[1] Wright of the Modiolaris Zone, and although not so deep as the type specimen, are identical with varieties found along with the latter.

FIG. 7.

A. De 1154 *B*. De 1144 *C*. De 1203

In a highly variable assemblage such as that under description, it is inevitable that there should be some forms of a more or less novel aspect, which hardly seem to simulate any known species. Three such are shown in Fig. 7. A is really not far from the norm of *C. fallax*, but B has little resemblance to that species. C closely approaches the type of *C. acuta* (J. Sowerby) except that it lacks sub-umbonal depth and is rather small for that species. As a variant from *C. fallax* it is interesting to compare it with the extreme variants from *C. protea* Wright shown in Fig. 13.

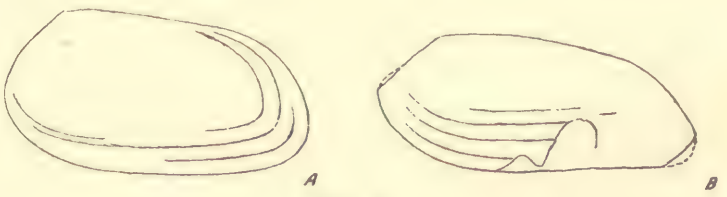


FIG. 8.

A. De 1240 *B*. De 1140

Variants from C. protea.—There is much variation in the relative depth of *C. protea* (see p. 14), and the more elongate forms approximate to large specimens of *C. fallax*. It is by no means clear that they are distinct species. Fig. 8 indicates a possible transition. The variation of *C. protea* follows somewhat similar lines to that of *C. fallax*, and produces forms very strikingly different from the original. The gradualness of the transitions cannot, however, be demonstrated in as satisfactory a manner on account of the size of the specimens, only a few of which can be included in an ordinary sized figure. There is a considerably lesser development of *Anthracomya*-like forms.

[1] *Ibid.*, p. 140, fig. 51 A, B.

Development of C. obliqua from C. protea.—Starting from the elongated form of *C. protea* shown in Fig. 8A, a decrease in the apical angle and reduction in the height of the posterior truncation leads to Fig. 9A, from which *C. obliqua* Wright is developed by increase in the prominence of the umbones as shown in Fig. 9B. The maximum of *C. obliqua* occurs at a slightly higher horizon in the Lower Coal Measures (see p. 20), which, however, is not separated from the beds above the Bassy Mine by such a marked stratigraphical interval as to make it difficult to conceive of the form found in the lower level having a direct genetic connexion with that on the higher.

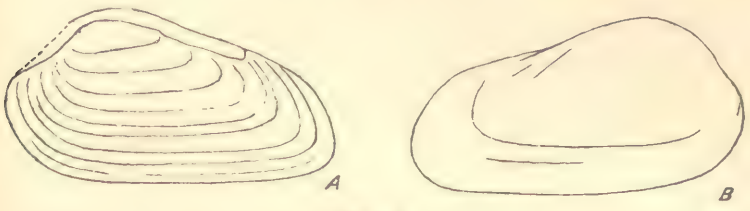


FIG. 9.

A. De 1160 *B.* De 1144

The Retrotracta-Variation of C. protea.—*Carbonicola retrotracta* Wright, being confined to a limited range in the Modiolaris Zone, has been regarded as one of the best fossils of the Middle Coal Measures of Lancashire for the purpose of fixing horizon. Although it can hardly be claimed that the forms above the Bassy Mine which simulate it are true to type, they nevertheless reproduce its essential distinctive character, and are sufficiently near to deceive, if considered apart from their associates and surroundings. They appear to be produced from an elongated form of *C. protea* by excessive postero-ventral growth resulting in tilting of the growth-lines and umbos. The nearest approximation to *C. retrotracta* is shown in Fig. 10. Other

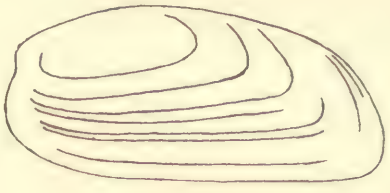


FIG. 10.
De 1275

examples are nearer *C. protea* (*e.g.*, Dw 1610 and De 1277). It is clear that a similar result could be obtained by another route, namely the *aquilina*-variation of *C. fallax*. Specimen De 1277 shows the possibility of this.

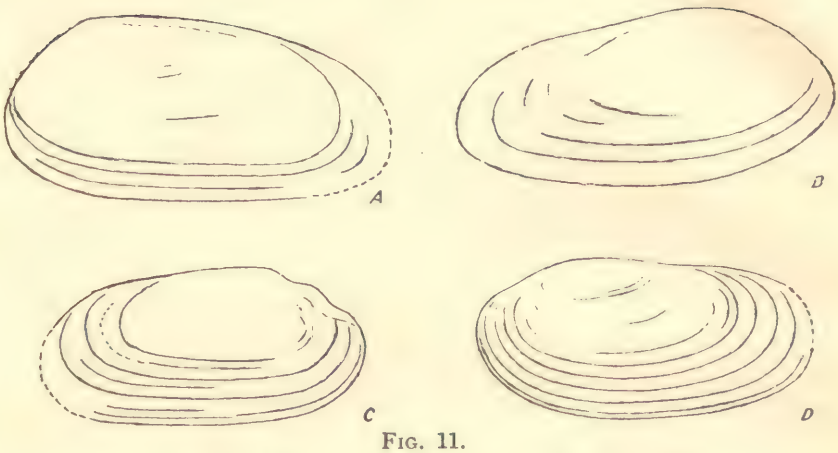


FIG. 11.

A. Dw 1582 *B*. Dw 1584
C. De 1211 *D*. De 1212

The Ovalis-Variation of C. protea.—Another variant from the elongate form of *C. protea* is identical with *C. ovalis* (Mart.). It is produced by the curvature of the margins and the rounding off of all angles, and the ultimate product is almost true to the type of that species. In Fig. 11, A and C are not far removed from *C. protea,* but have a definitely rounded posterior truncation. B, on the other hand, has a curved lower margin. The coincidence in one specimen of both these variations produces D, which is indistinguishable from *C. ovalis*. Specimens De 1320 and Dw 1577 are further examples. The change is clearly comparable with

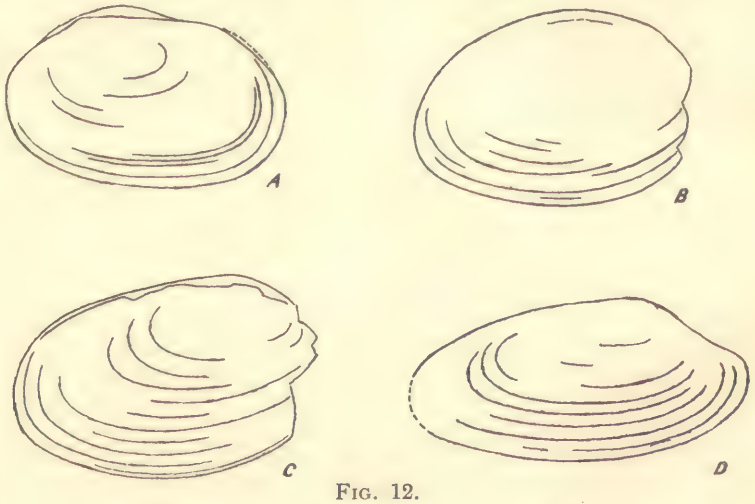


FIG. 12.

A. De 1230 *B*. De 1241
C. Dw 1647 *D*. De 1216

that from *C. fallax* to *C. faba* shown in Fig. 6. Since the maximum of *C. ovalis* is in the Lower Coal Measures, although at a considerably higher horizon, a genetic connexion with this form is just possible, but less probable than in the case of *C. obliqua*.

There is also a variation from the deeper or type form of *C. protea*, which results in large shells of the form of *C. regularis* Trueman and *C. elliptica*. This is shown in Fig. 12, and specimens Dw 1647, Dw 1697, De 1219 and De 1241 also illustrate this variation. Similar forms are recorded from the Modiolaris Zone of Yorkshire by Professor Trueman.[1]

Simulation of C. communis and C. acuta.—The production of a series of forms leading up to an extreme variant with acutely tapering posterior end is one of the most remarkable features of this horizon. In Fig. 13 A is not far removed from *C. protea*, B

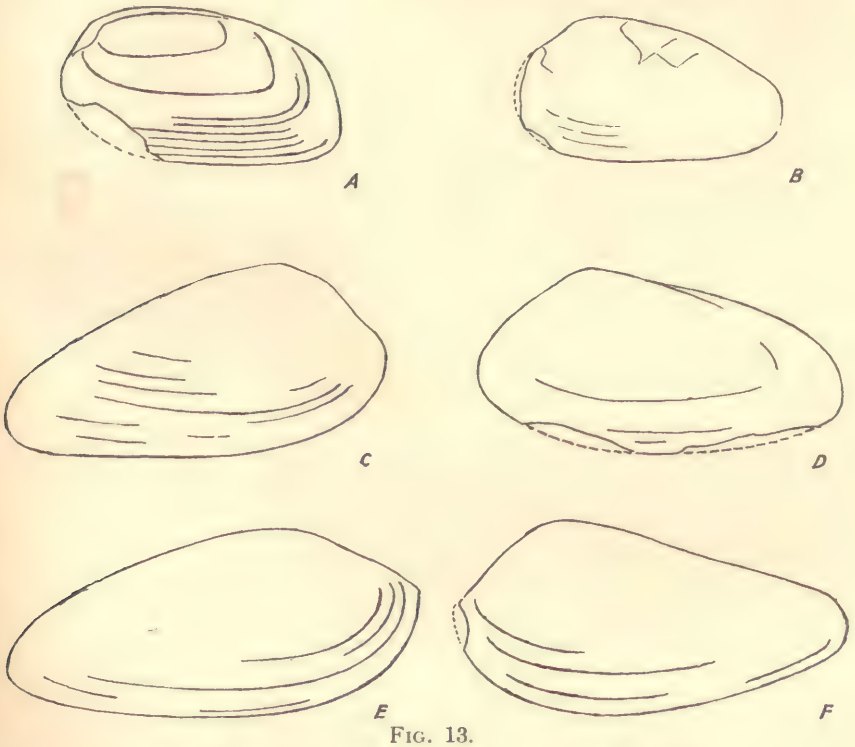


FIG. 13.

A. De 1191A
B. De 1152
C. De 1312
D. De 1884
E. De 1889
F. De 1888

is close to *C. communis* Davies and Trueman, C, D and E show approximations in form to *C. acuta*. Specimens De 1159 and De 1310 also illustrate the change. A still further variant with curvature of the lower border as in F, but often even more extreme

[1] Trueman, A. E., 'Some new Carboniferous Lamellibranchs,' *Ann. Mag. Nat. Hist.* Ser. 10, vol. iv, 1929, p. 92.

than that shown by this specimen, is also present, but is not represented by any other specimens good enough for figuring. Specimens De 1881, De 2107 and De 2114 are examples.

In connexion with this last-mentioned variation with pronounced curvature of the lower margin, it is worth noting that a somewhat similar form is preserved in the Manchester Museum labelled 'Tyldesley, Lancashire, Brassey Mine, Middle Coal Measures.' The Brassey Mine is, however, well exposed in the open at Tyldesley ('Geology of Manchester' *Mem. Geol. Surv.* 1931, p. 104) and has no shell-bed above it, nor is any such known in any part of the coalfield, so it is likely there is some mistake regarding horizon. The idea that the label should read 'Bassy' instead of 'Brassey' is hardly tenable, since the Bassy Mine is not accessible anywhere near Tyldesley. Besides, it adds explicitly 'Middle Coal Measures.' Moreover the form is not quite the same as that above the Bassy Mine, having a short posterior truncation. It has been labelled by Hind *C. acuta* var. *ovalis*, but is not referred to in his monograph or papers.

Carbonicola haberghamensis and allied forms.—The forms embraced under this heading are a rather promiscuous lot agreeing only in having more or less *Anthracomya*-like characters, that is to say they have a well developed 'hinge-line' emerging from between the umbos and nearly parallel with the general direction of the lower border. Fig. 5, p. 16, shows two forms of *C. haberghamensis*, with long and short hinge-lines respectively, and Fig. 14 C and D two more definitely *Anthracomya*-like

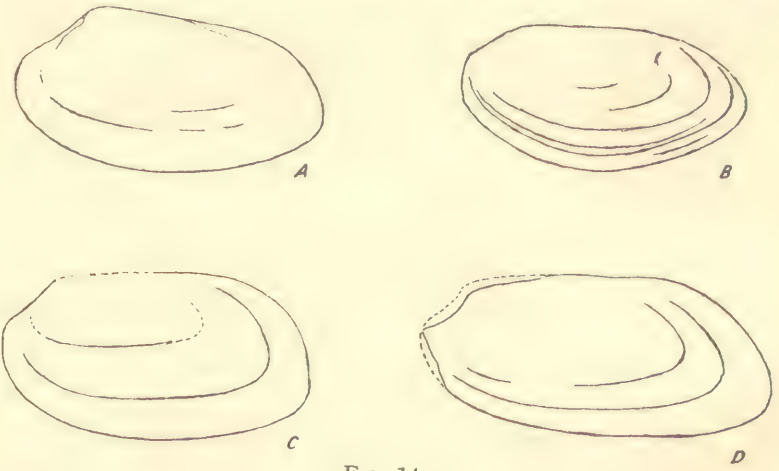


FIG. 14.

A. Dw 1613
B. Dw 1624
C. Dw 1684
D. Dw 1623

variations, while Fig. 14 A and B shows two rather aberrant forms, which it seems desirable to figure to avoid giving an unwarranted appearance of constancy in type.

Possible Passage from C protea to C. recta.—A passage from *C. protea* to *C. recta* Trueman is not obvious and *C. recta* is certainly rare in the beds between the Bassy and Lower Foot Mines, only becoming an element of importance in the fauna on the level of the Lower Foot and Lower Mountain Mines, especially above the latter. The characters by which it is to be distinguished from *C. protea* are a lesser apical angle, increase in the posterior-inferior angle with approximation of the latter to 90°, and straightness of the lower border (see Fig. 7, p. 20.)

Small shells otherwise resembling *C. fallax* occasionally develop a posterior-inferior angle of approximately 90° and so approach *C. recta, e.g.* Dw 1613C.

C. recta seems to come in shortly above the Six Inch Mine, on which horizon *C. protea* has not been found. It may therefore be independent.

Character of the Fauna as a whole.—The initial effect produced by reviewing a fauna as variable as that above the Bassy Mine is despair regarding the possibility of using such fossils as *Carbonicola* and *Anthracomya* for zonal purposes. It remains yet to be proved, however, that the fauna on any other horizon shows such a wide range of variation. Even if this should be the case it may be possible to determine norms and characteristic variations, which render the faunas distinguishable from one another. The case studied above reveals the following distinctive characters.

(1) *Carbonicola aquilina* which is dominant in the Modiolaris Zone is only a rare variant in the Lower Coal Measures.
(2) *Carbonicola fallax* which is dominant in the Lower Coal Measures is a rare variant in the Modiolaris Zone.
(3) The variants *C. haberghamensis* and *C.* cf. *acuta* are unmistakably distinct and have not been found on any other horizon in Lancashire.
(4) *C. obliqua* ascends to within a short distance of the Arley Mine but has not been found above it.
(5) No shell closely resembling *C. protea* has yet been figured from any other horizon, but it might be easily simulated by *C. rhomboidalis.*

A criterion of a different kind lies in the order of succession of the forms, for the simulations of higher forms which are liable to mislead are mingled together in these beds, whereas the simulated species themselves occupy distinct horizons, or at least reach their maxima on distinct horizons, in the Modiolaris and Pulchra Zones of the Middle Coal Measures.

It is obvious, however, that extreme caution has to be taken in the employment of species of *Carbonicola* and *Anthracomya* as zonal indices. The mere finding of what appears to be a zonal form in an isolated exposure may be positively misleading. It

becomes necessary to collect and study the whole fauna before any judgment can justifiably be passed as to the horizon represented. Moreover, since the range of variation of very few faunas is exhaustively known, a judgment of the kind still has elements of danger, unless some accessory evidence such as relation to other faunas above and below, or else distinctive stratigraphical relations, can be brought to bear on the question. The danger of error clearly increases with distance from the type section, and any spotting of zones in new areas from a few specimens is highly unscientific.

The fresh-water faunas on different horizons of the Coal Measures have, however, sufficient distinctness to lend character to the strata in which they occur, and, if carefully used, with proper appreciation of their limitations as criteria of horizon, greatly facilitate local correlation and afford some basis for wider correlations of a less exact nature. It is going too far to claim for them a reliability any greater than this.

IV.—THE FAUNA OF THE LOWER COAL MEASURES IN WEST YORKSHIRE

BY

D. A. Wray, Ph.D., M.Sc., F.G.S. and

Professor A. E. Trueman, D.Sc., F.G.S.

WITH

NOTES ON THE LOWER COAL MEASURE FOSSILS FROM MESSRS. JARMAIN'S BORING, KIRKHEATON, NEAR HUDDERSFIELD

BY

Professor A. E. Trueman, D.Sc., F.G.S. and

J. Wilfrid Jackson, D.Sc., F.G.S.

Plates III, IV.

Introduction

THE Lower Coal Measures in West Yorkshire consist of an alternating series of mudstone, shale and sandstone with occasional beds of coal, fireclay, ganister and ironstone. As originally defined by Phillips they include the measures extending from the Rough Rock to the top of the Elland Flags and have an average thickness of about 850 feet. During the survey of the Yorkshire coalfield, however, some sixty years ago, the officers of the Geological Survey found the Silkstone or Blocking Coal (a somewhat higher horizon) a more convenient datum-line to trace than the top of the Elland Flags and consequently adopted it as the upper limit of the Lower Coal Measures. This procedure has been generally followed, though the present writers consider that the original limits adopted by Phillips are more in accordance with the fossil evidence and they are consequently followed in the present communication.[1]

The coal-seams chiefly occur in the lower part of these measures. They have been somewhat extensively worked in the past along the outcrop and consequently the fauna of the Lower Coal Measures is chiefly known from the strata in the immediate proximity of these coal-seams. Of these, the marine fauna associated with the roof-shales of the Halifax Hard Bed Coal and the molluscan band which overlies the Soft Bed Coal, each of which has a

[1] This subject has already been fully discussed elsewhere. See especially D. A. Wray, 'The Major Subdivisions of the Coal Measures in Yorkshire,' 'Summary of Progress' for 1931 Part II (*Mem. Geol. Surv.*), 1932, pp. 56-68 and references there given.

wide distribution, are the best known. Within recent years the Lower Coal Measure succession in Yorkshire has been studied by the Geological Survey, and numerous other fossil bands have been recognised.[1] Additional information has also been obtained from several deep borings carried through these measures.[2] Within the past year a deep boring at Kirkheaton near Huddersfield has given us an additional opportunity of examining practically the whole of the Lower Coal Measure succession below the Elland Flags. The boring was made by Messrs. Thos. Matthews and Co., Artesian Well Engineers of Manchester, on behalf of Messrs. Jarmain and Son at their works, the Minerva Mills,[3] Kirkheaton. We are much indebted to G. G. Jarmain, Esq. and the boring firm for granting us every facility to examine the extensive series of cores obtained. A remarkably complete and well-preserved series of cores was obtained and their examination has revealed the presence of no less than six distinct marine horizons, of which three are recorded for the first time from these measures. In addition non-marine lamellibranchs occurred at sixteen horizons and this has considerably increased our knowledge of the faunal succession in these rocks. The marine fossils have been named by Dr. J. W. Jackson of the Manchester Museum, while one of us (A.E.T.) has examined the non-marine lamellibranchs.

A measured section of the Lower Coal Measures in the Huddersfield district is shown in Plate III. From the Rough Rock to the base of the Elland Flags the measurements are based on those observed in Messrs. Jarmain's boring at Kirkheaton, referred to above. This represents the full development of these measures in West Yorkshire, and also corresponds very closely with the section observed during the sinking of the adjacent colliery shaft at the Victoria Collieries, Lepton,[4] which was sunk to the Soft Bed Coal. This sinking, however, commenced at the level of the Better Bed Coal and thus the combination of the two records gives a complete measured section of the Lower Coal Measures in the Huddersfield district.

When the present paper was almost completed, the writers learned that Dr. W. B. Wright had prepared an account of the Lower Coal Measure sequence in Lancashire, and had named some new species. They are greatly indebted to Dr. Wright for allowing them to see his work in manuscript and to make some use of his results.

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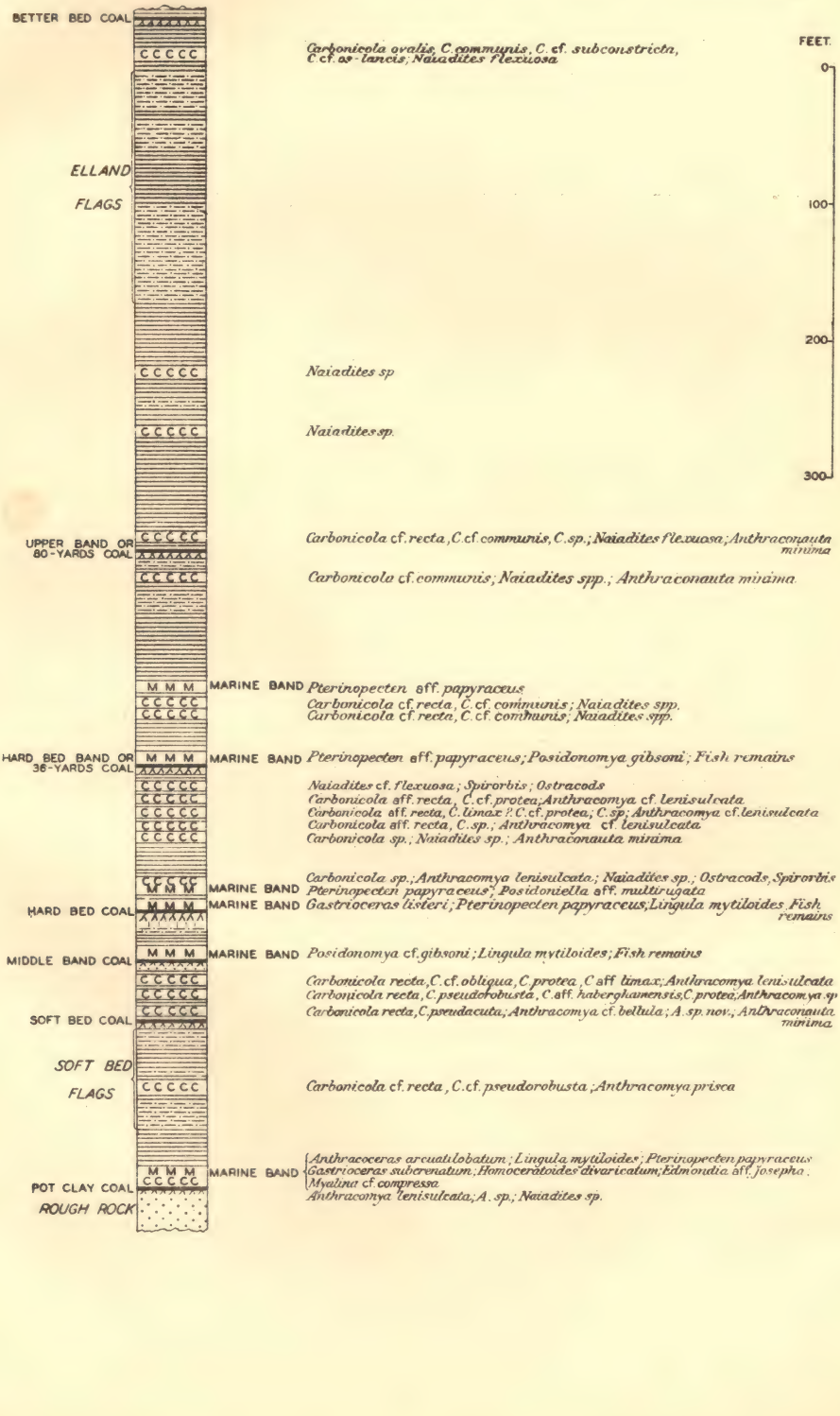
[1] 'The Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, pp. 48-89, and D. A. Wray, 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 250-275.

[2] Wray, D. A., and S. Melmore, 'Notes on some recent deep Borings at Huddersfield,' *Proc. Yorks. Geol. Soc.*, vol. xxii, 1931, pp. 31-51.

[3] The site of the boring adjoins the Minerva Works, and is about 180 yds. due west of Kirkheaton Railway Station, near Huddersfield. Height above O.D., 200 ft. Six-inch Map: Yorkshire 246 S.E.

[4] See 'Sections of Strata of the Coal Measures of Yorkshire,' *Midland Inst. Min. Eng.*, Second Edition, 1927, Sheffield, p. 353.

THE LOWER COAL MEASURES OF WEST YORKSHIRE.


FEET.
0
100
200
300
BETTER BED COAL
Carbonicola ovalis, C. communis, C. cf. subconstricta, C. cf. ac-lancis; Naiadites flexuosa
ELLAND FLAGS
Naiadites sp
Naiadites sp.
UPPER BAND OR 80-YARDS COAL
Carbonicola cf. recta, C. cf. communis, C. sp.; Naiadites flexuosa; Anthraconauta minima
Carbonicola cf. communis; Naiadites spp.; Anthraconauta minima
MARINE BAND
Pterinopecten aff. papyraceus
Carbonicola cf. recta, C. cf. communis; Naiadites spp.
Carbonicola cf. recta, C. cf. communis; Naiadites spp.
HARD BED BAND OR 36-YARDS COAL
MARINE BAND
Pterinopecten aff. papyraceus; Posidonomya gibsoni; Fish remains
Naiadites cf. flexuosa; Spirorbis; Ostracods
Carbonicola aff. recta, C. cf. protea; Anthracomya cf. lenisulcata
Carbonicola aff. recta, C. limax ? C. cf. protea, C. sp.; Anthracomya cf. lenisulcata
Carbonicola aff. recta, C. sp.; Anthracomya cf. lenisulcata
Carbonicola sp.; Naiadites sp.; Anthraconauta minima
Carbonicola sp.; Anthracomya lenisulcata.; Naiadites sp.; Ostracods, Spirorbis
MARINE BAND
Pterinopecten papyraceus; Posidoniella aff. multirugata
HARD BED COAL
MARINE BAND
Gastrioceras listeri; Pterinopecten papyraceus; Lingula mytiloides. Fish remains
MIDDLE BAND COAL
MARINE BAND
Posidonomya cf. gibsoni; Lingula mytiloides; Fish remains
Carbonicola recta, C. cf. obliqua, C. protea, C aff. limax; Anthracomya lenisulcata
Carbonicola recta, C. pseudorobusta, C. aff. haberghamensis, C. protea; Anthracomya sp.
SOFT BED COAL
Carbonicola recta, C. pseudacuta; Anthracomya cf. bellula; A. sp. nov.; Anthraconauta minima
SOFT BED FLAGS
Carbonicola cf. recta, C. cf. pseudorobusta; Anthracomya prisca
MARINE BAND
Anthracoceras arcualilobatum; Lingula mytiloides; Pterinopecten papyraceus
Gastrioceras subcrenatum; Homoceratoides divaricatum; Edmondia aff. josepha.
Myalina cf. compressa
POT CLAY COAL
Anthracomya lenisulcata; A. sp.; Naiadites sp.
ROUGH ROCK

The Pot Clay Coal.—This coal, seldom exceeding an inch in thickness and resting on a thick bed of fireclay, appears to be represented throughout the North Midland coalfields. Its roof consists of highly fossiliferous shales in which several distinct bands can be recognised, the lower half containing non-marine forms exclusively, and the higher marine shells only. Full details of these have already been given elsewhere.[1]

The fauna of the lower band includes *Anthracomya lenisulcata* Trueman, and allied forms, including a form resembling *Anthracomya macadami*, var. *subparallela* Hind; and *Naiadites sp.* The marine band yields *Gastrioceras subcrenatum* (Schlotheim MS.) C. Schmidt and allied forms, and *Homoceratoides divaricatum* (Hind), in the lower part; and *Anthracoceras arcuatilobatum* (Ludwig) in the upper portion. *Lingula mytiloides* J. Sowerby, and the lamellibranchs *Pterinopecten papyraceus* (J. Sowerby) and *Posidonomya gibsoni* (Salter), occur throughout the marine shales but are more abundant in the upper portion. At the base of the marine band in the Minerva Mills boring there occurred some well preserved shells of the genus *Edmondia*, which closely resemble *Edmondia josepha* de Koninck, and may belong to a new species. These have been described by Dr. J. W. Jackson (see page 47). Associated with them was a single valve of *Myalina* cf. *compressa* Hind.

A second and higher band with non-marine lamellibranchs occurs about seventy feet above the Pot Clay Coal and appears to have a wide distribution in Yorkshire.[2] *Anthracomya prisca* Trueman and forms closely resembling *Carbonicola pseudorobusta* Trueman, and *Carbonicola recta* Trueman occur on this horizon.

The Soft Bed Coal.—The *Carbonicola* band which occurs in the shales overlying this coal-seam is probably one of the best known in the whole of the Lower Coal Measure succession. It has frequently been described as a characteristic feature of the roof-shales of this coal, and a similar band occurs throughout the North Midland coalfields at a corresponding horizon.[3] In the boring at the Minerva Mills, Kirkheaton, there were three main bands crowded with impressions of non-marine lamellibranchs at levels of six feet, eighteen to twenty feet, and twenty seven feet respectively, above the Soft Bed Coal. The shales between these bands also yielded indistinct and poorly preserved non-marine lamellibranchs.

Throughout these shales, shells related to *Carbonicola recta* Trueman are abundant. That species is well represented, together

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[1] Wray, D. A., and S. Melmore, 'Notes on some recent deep Borings at Huddersfield,' *Proc. Yorks. Geol. Soc.*, vol. xxii, 1931, pp. 42-44.

[2] Wray, D. A., and A. E. Trueman, 'The Non-marine Lamellibranchs of the Upper Carboniferous of Yorkshire and their Zonal Sequence,' 'Summary of Progress' for 1930 Part III (*Mem. Geol. Surv.*), 1931, pp. 72, 73.

[3] Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 258-260.

with forms identical with *C. protea* W. B. Wright and others which resemble *C. haberghamensis* W. B. Wright (Pl. IV, fig. 7). There are also numerous variants differing in the height of the shell and in curvature of the lower border, but all are apparently related to *C. recta* (Pl. IV, figs. 6-12). They exhibit general agreement in the blunted aspect of the posterior end, a feature by which they can be readily distinguished from the *Carbonicola communis* group which characterises the lower part of the Middle Coal Measures.

In the lowest band, six feet above the Soft Bed Coal at the Minerva Mills boring, *Anthracomya* is represented by a distinctive form which may belong to a new species (see page 46) while impressions of *Naiadites sp.* are also common. In the highest of the three bands *Anthracomya lenisulcata* Trueman is abundant. The remaining fauna of the Soft Bed ' Carbonicola ' band includes *Carbonicola pseudorobusta* Trueman, *Anthracomya* cf. *bellula* Bolton, and *Anthraconauta minima* (Ludwig), while from one locality we have recorded a form closely resembling *Carbonicola ovalis* (Martin).[1]

Fish remains have also been recorded from the roof-shales of the Soft Bed Coal in the Halifax district. They include *Pleuroplax attheyi* (W. J. Barkas), *Pleuroplax rankinei* (Hancock and Atthey), *Hoplonchus elegans* Davis, *Coelacanthus elegans* Newberry, *Megalichthys coccolepis* Young, *Megalichthys hibberti* Ag., and *Rhadinichthys monensis* (Egerton).[2]

The Middle Band Coal.—Between the Soft Bed and Hard Bed coals there usually occurs a seam of coal known as the Middle Band, which is too thin to be worked and is therefore rarely seen except in sinkings or borings. In many places the roof-shales of this coal consist of black cannel-like shale with abundant comminuted fish remains. The commonest forms appear to be the fin spines *Acanthodes wardi* Egerton, and the scales of *Elonichthys binneyi* Traq., and *Rhadinichthys monensis* (Egerton). At Honley near Huddersfield and at Halifax *Lingula sp.* occurs in the roof-shales of the Middle Band Coal. In the boring at the Minerva Mills, Kirkheaton, a band crowded with *Posidonomya* immediately overlay the coal-seam. These according to Dr. J. W. Jackson are probably young forms of *Posidonomya gibsoni* (Salter). This band was not more than one inch thick and its upper surface was covered with well-preserved impressions of *Lingula mytiloides* J. Sowerby.

The Hard Bed Coal.—The presence of marine fossils in the roof-shales of this coal is one of the most widely known features of the Lower Coal Measures. In the boring at the Minerva Mills there was a total thickness of 110 feet of measures, mainly consisting of shale, between the Hard Bed Coal and the next succeeding seam,

[1] Wray, D. A. and A. E. Trueman, *op. cit.*, p. 73.
[2] Recorded by Dr. E. D. Wellburn of Sowerby Bridge in various papers. See 'The Geology of the Country around Huddersfield and Halifax' *Mem. Geol. Surv.*), 1930, pp. 157-160.

the Hard Bed Band or 36-Yards Coal. Of these the lowest fourteen feet yielded marine fossils. Fine black shales up to four feet in thickness yielding *Gastrioceras listeri* (Martin) and allied forms, *Pterinopecten papyraceus* (J. Sowerby) and *Lingula mytiloides* J. Sowerby rested directly on the coal. This was succeeded by ten feet of black shale in which only the brachiopod *Lingula* occurred sporadically. At a distance of fourteen feet above the coal, a highly fossiliferous band occurred and this yielded *Pterinopecten papyraceus* (J. Sowerby) in abundance and also small lamellibranchs closely resembling *Posidoniella multirugata* J. W. Jackson. No goniatites however appeared to be present on this horizon.

Five feet higher, or 19 feet above the Hard Bed Coal, a band with non-marine lamellibranchs was met with. *Anthracomya lenisulcata* Trueman was the dominant form but in addition there occurred impressions of *Carbonicola* and *Naiadites*. Ostracods and *Spirorbis* were also abundant in this fossiliferous bed of shale. This was succeeded by a thick series of shales apparently devoid of fossils.

From the roof-shales of the Hard Bed Coal in the Halifax district, Dr. Wellburn has recorded numerous fragmentary fish remains (see Footnote, page 40). These include *Helodus sp.*, *Janassa sulcatus* Wellb., *Pleuroplax attheyi* (W. J. Barkas), *Pleuroplax rankinei* (Hancock and Atthey), *Hoplonchus elegans* Davis, *Acrolepis hopkinsi* (M'Coy), *Cheirodus granulosus* (Young), *Coelacanthus elegans* Newberry, *Coelacanthus phillipsi* Ag., *Elonichthys aitkeni* Traq., *Elonichthys semistriatus* Traq., *Megalichthys hibberti* Ag., *Rhadinichthys monensis* (Eg.), *Rhizodopsis sauroides* (Will.), and *Strepsodus sauroides* (Binney).

In the shales sixty to ninety feet above the Hard Bed Coal non-marine lamellibranch shells are very abundant and an extensive collection was made from the better preserved material at levels of 62, 67, 70, 82 and 90 feet respectively above the coal. The band at 62 feet was characterised by an elongate species of *Carbonicola*, while *Naiadites* was represented by narrow and oblique forms. *Anthraconaula minima* (Ludwig) also occurred in this band. In the bands at 67, 70 and 82 feet respectively *Carbonicola sp.* similar to that in the underlying bed at 62 feet occurred, associated, however, with other forms exhibiting close affinities with *Carbonicola recta* Trueman, a form hitherto regarded as distinctive of the lowest part of the Lower Coal Measures. These shells are variable and include forms which should possibly be referred to *C. obliqua* W. B. Wright, but the specimens are not sufficiently well preserved to admit of definite identification. In these bands there also occur numerous elongated shells, resembling in general form *C. concinna* W. B. Wright: they probably include variants of *C. limax* W. B. Wright and *C fallax* W. B. Wright (Pl. IV, figs. 4, 5). In these bands *Anthracomya* was represented by forms closely resembling *Anthracomya lenisulcata* Trueman but there were some shells which cannot definitely be placed with either *Carbonicola* or *Anthracomya*, appearing to be intermediate in

general shape between *A. lenisulcata* and *C. fallax*. The highest fossiliferous band at ninety feet yielded principally impressions of *Naiadites*, closely resembling *Naiadites flexuosa* Dix and Trueman,[1] together with *Spirorbis* and Ostracods.

The Hard Bed Band and 36-Yards Coals.—These two thin unimportant seams of coal separated by a few feet of fireclay occur together only in the neighbourhood of Elland, the lower one, the Hard Bed Band, dying out in a northerly direction, and the 36-Yards, absent to the south of Elland, alone persisting to the north of that town. Consequently only one coal is normally present at this horizon and it is variously referred to as the 36-Yards, Hard Bed Band, or sometimes simply as the ' Band ' Coal. The thick bed of fireclay underlying it is of considerable economic importance and is worked in many places.

In the boring at the Minerva Mills, Kirkheaton, there were, in all, 157 ft. of measures between the 36-Yards or Hard Bed Band Coal and the next succeeding seam, the Upper Band Coal. It consisted largely of shale and in it occurred two bands with marine fossils and three with non-marine lamellibranchs.

The lower marine band, six inches above the Hard Bed Band Coal, was an extremely thin band of dull black papery shale crowded with flattened impressions of *Pterinopecten sp.* and *Posidonomya* cf. *gibsoni* (Salter). Fish scales referable to the genus *Elonichthys* occurred in addition. From the roof-shales of the 36-Yards Coal in the Halifax district Dr. E. D. Wellburn has described similar fish scales under the specific name *Elonichthys obliquus* Wellburn.

The higher marine band fifty-two feet above the coal was remarkably similar to the lower one and the fossils consisted exclusively of flattened impressions of *Pterinopecten*. They are poorly preserved and referred to as *Pterinopecten* aff. *papyraceus* (J. Sowerby) by Dr. J. W. Jackson.

The three *Carbonicola* bands occured at 34, 37 and 133 ft. respectively above the Hard Bed Band Coal. The two lower bands yield elongated shells related to *Carbonicola recta* Trueman, and also others which resemble *Carbonicola communis* in general outline. *Naiadites sp.* also occurs in these bands. The fauna of the highest bed, 133 ft. above the Hard Bed Band Coal, includes shells closely resembling *Carbonicola communis* J. H. Davies and Trueman, *Naiadites spp.*, of very narrow oblique outline, and *Anthraconauta minima* (Ludwig).

The Upper Band or Eighty-Yards Coal.—A thin trace of coal occurred at this level in the boring at the Minerva Mills, resting on five feet of good fireclay. Throughout Yorkshire the Upper Band Coal is thin and not always present. There is, however, usually a bed of fireclay or thin band of ganister-rock on this horizon. Between the Upper Band Coal and the base of the Elland Flags

[1] Dix, E. and A. E. Trueman, ' Some Observations on the Genus *Naiadites*,' *Annals and Mag. Nat. Hist.*, Ser. 10, vol. ix, 1932, pp. 12, 14.

there is about 170 ft. of measures in the Huddersfield district consisting mainly of shale. Hitherto only *Anthraconauta* cf. *minima* (Ludwig) has been recorded from these measures,[1] but in the cores of the boring at Minerva Mills non-marine lamellibranchs occurred at three horizons, *viz.* 7 ft., 87 ft. and 130 ft. respectively above the Upper Band Coal. The lowest band yielded forms resembling *Carbonicola recta* Trueman, and others which may be described as *Carbonicola* cf. *communis* J. H. Davies and Trueman, being possibly related to that species. Another species of *Carbonicola* is represented by a thin shell with radial ornament. There are also shell-casts closely resembling *Naiadites flexuosa* Dix and Trueman. The two higher bands at 87 ft. and 130 ft. respectively yielded only impressions of *Naiadites*, those in the highest bed being in a very poor state of preservation. The forms of *Naiadites*, however, from 87 ft. above the Upper Band Coal are characterised by the possession of a very notable ' wing ' (see Plate IV, fig. 2).

The measures between the Elland Flags and Better Bed Coal.—There are usually one or more shale partings in the Elland Flags but we have hitherto been unable to find any fossiliferous bands in these measures. To the south-east of Huddersfield the Better Bed Coal and its underclay rest directly on the topmost bed of the Elland Flags. North of Fenay Bridge, however, a certain amount of shale separates the Better Bed Coal from the top of the Elland Flags and in the neighbourhood of Rastrick it attains a thickness of as much as fifty feet. In this shale parting at Rastrick Mr. James Walton has traced a thin band of impure limestone crowded with calcite shells of *Carbonicola* and *Naiadites* for a distance of upwards of a mile. This band, which occurs about thirty feet below the Better Bed Coal, contains abundant casts of *Carbonicola ovalis* (Martin), *Carbonicola communis* J. H. Davies and Trueman, and *Naiadites flexuosa* Dix and Trueman. Other fossils include *Carbonicola* cf. *subconstricta* (J. Sowerby), *Carbonicola* cf. *os-lancis* W. B. Wright, and a form described as *Carbonicola* aff. *communis* J. H. Davies and Trueman, which shows some resemblances to *Carbonicola polmontensis* (Brown).[2] A thin calcareous band with a similar fauna has also been observed at a corresponding horizon in the neighbourhood of Leeds.[3]

General Observations on the Faunal Succession

The three marine bands which overlie the Pot Clay, Middle Band and Hard Bed coals respectively have been previously observed in Yorkshire and it has also been shown that they are each represented throughout the North Midland coalfields.[4] The two marine beds which occur in the measures above the Hard Bed

[1] Wray, D. A., and A. E. Trueman, *op. cit.*, p. 73.
[2] Walton, J., ' Non-marine Lamellibranchs between the Better Bed Coal and the Elland Flags,' *The Naturalist*, 1932, p. 121.
[3] Edwards, Wilfrid, ' The Geological Structure of Leeds,' *Trans. Leeds Geol. Assoc.*, vol. v., 1930-31, p. 6.
[4] Wray, D. A., ' The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 253-265.

or 36-Yards Band Coal are recorded for the first time from the Yorkshire Coalfield. In the Lancashire Coalfield, however, a marine band was recorded in 1910 by Mr. A. J. Tonge from the Chequerbent colliery sinking, in measures on about the same geological horizon.[1] This bed, usually referred to as 'Tonge's Marine Band,' has also been found in the Bolton district and occurs about sixty feet above the Upper Mountain Mine Coal.[2] It has been pointed out that the latter seam corresponds closely with the Hard Bed Band or 36-Yards Coal of Yorkshire,[3] so that Tonge's Marine Band in Lancashire would appear to be represented in Yorkshire by the marine band in the Minerva Mills boring which occurs 52 ft. above the Hard Bed Band Coal.

The marine band with *Pterinopecten* aff. *papyraceus* (J. Sow.) and *Posidonomya gibsoni* (Salter) which immediately overlies the Hard Bed Band Coal in the Minerva Mills boring at Kirkheaton has not been observed elsewhere. We have been unable to find it, in fact, at any other locality in Yorkshire though admirable sections of these measures have been seen in the fireclay workings in the neighbourhood of Elland and Halifax.

It is unfortunate that the marine fauna in the Lower Coal Measures includes goniatites only at two horizons. The lamellibranchs and brachiopods have not the same zonal value for the purposes of correlation with other areas; moreover, the goniatites represented in the two bands both belong to the genus *Gastrioceras*.

The succession of a band with *Gastrioceras* followed by shales with *Lingula sp.* and finally overlain by a band with marine lamellibranchs above the Hard Bed Coal in the Minerva Mills boring does not appear to have been previously recorded elsewhere.

The faunal variations at successive horizons observed here and also recorded from the measures above the Pot Clay Coal in other borings at Huddersfield,[4] would appear to indicate that varying bathymetrical conditions succeeded the deposition of these two coal-seams.

While the marine bands are extremely useful for the purposes of the correlation of measures in adjacent areas, the non-marine lamellibranchs yield more valuable results than the marine fossils for zonal purposes and consequently for the comparison of the succession in other coalfields.

The discovery at Rastrick, near Brighouse, of a fauna characteristic of the *Carbonicola ovalis* Zone in the measures between the Elland Flags and the Better Bed Coal[5] has already shown the necessity for some minor revision of the original zonal boundaries

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[1] Tonge, A. J., *Trans. Manch. Geol. Soc.*, vol. xxxi, 1908-10, pp. 254-266.

[2] Tonks, L. H., and others, 'The Geology of Manchester and the South-East Lancashire Coalfield' (*Mem. Geol. Surv.*), 1931, p. 32.

[3] Wray, D. A., *op. cit.*, p. 268.

[4] Wray, D. A., and S. Melmore, 'Notes on some recent deep Borings at Huddersfield,' *Proc. Yorks. Geol. Soc.*, vol. xxii, 1931, pp. 42-44.

[5] Walton, J., 'Non-marine Lamellibranchs between the Better Bed Coal and the Elland Flags,' *The Naturalist*, 1932, p. 121.

we had instituted in 1931.[1] The present investigations, however, indicate that there is in reality a gradual change in the fauna of the Coal Measures from the base upwards.

The most characteristic fossils of the lower part of the Lower Coal Measures are *Anthracomya lenisulcata* Trueman, the zonal form, together with *Anthracomya prisca* Trueman, *Carbonicola recta* Trueman and allied forms. In the measures above the Hard Bed Coal, an elongated shell with fine ornamentation somewhat resembling *Carbonicola concinna* W. B. Wright or *C. acutella* W. B. Wright is fairly common and appears to be a characteristic fossil at this horizon. Unfortunately it is generally in too poor a state of preservation to identify it definitely with any of the new species established by Dr. Wright.

The first appearance of any shells which can be referred to the *Carbonicola communis* group occurs in the measures above the 36-Yards or Hard Bed Band Coal, or about midway in the Lower Coal Measures succession. In these beds, however, they are associated with forms which belong to the *Carbonicola recta* group, the latter being especially characteristic of the lower beds and, though occurring sparingly in the higher part of the Lower Coal Measures, are apparently absent from the Middle Coal Measures.

Naiadites flexuosa Dix and Trueman, though fairly common in the higher part of the Lower Coal Measures, has not hitherto been observed below the Hard Bed Coal. A more oblique form which may prove of some zonal value appears to take its place in the lowest Coal Measures.

While, however, there is a gradual faunal change upwards in the Coal Measures, none of the lower horizons have so far yielded a fauna so characteristic of the *Carbonicola ovalis* Zone as that described above from the measures between the Elland Flags and the Better Bed Coal at Rastrick. It seems appropriate therefore to adopt the top of the Elland Flags as the base of the *Carbonicola ovalis* Zone.

The fragmentary fish remains which occur at several horizons in the Lower Coal Measures have been found throughout the main mass of the Coal Measures, and as yet no form can be referred to as distinctive of the Lower Coal Measures.

NOTES ON THE FOSSILS FROM THE LOWER COAL MEASURES IN MESSRS. JARMAIN'S BORING, KIRKHEATON

1. The Non-Marine Shells

BY

PROFESSOR A. E. TRUEMAN, D.Sc., F.G.S.

The non-marine shells obtained from this boring and described in the foregoing pages afford the best material yet available from

[1] Wray, D. A., and A. E. Trueman, *op. cit.*, pp. 72-74.

many horizons in the Lower Coal Measures of Yorkshire. It is greatly to be regretted that the shells are in many cases badly preserved and are too incomplete to yield satisfactory types on which to base new species. Some of them resemble species which have been named by Dr. W. B. Wright, but it is rarely possible to make a definite identification, for the shells usually represent variants which differ to some extent from the types of those species.

Carbonicola

In the lower part of the sequence, shells which are allied to *Carbonicola recta* Trueman are most abundant. Those from some distance above the Soft Bed Coal are quite typical but are associated with variants in which the anterior end is shorter than in the holotype of the species, and others in which a distinct angle is developed at the posterior end of the lower border (Pl. IV, figs. 9, 10). These variants include forms identical with *C. protea* W. B. Wright. Occasional specimens, with a well rounded lower border, are probably related to *C. haberghamensis* W. B. Wright (Pl. IV, fig. 7), while others approach *C. pseudacuta* Trueman (Pl. IV, fig. 11).

It is probable, however, that all these shells can be regarded as variants from the one species, *C. recta* Trueman.

In the higher strata, from sixty to ninety feet above the Hard Bed Coal, there also occur numerous shells which are probably related to the same group. Many of them differ from the type of *C. recta* in having a gently curved lower border and growth lines, while some have a much shorter anterior end than is typical of that species. Some of these variants may be referable to *C. obliqua* W. B. Wright.

Associated with these shells are Carbonicolas which may represent another group. They consist of more elongated shells, with fine growth lines and often with a thin shell, some of them resembling *C. concinna* W. B. Wright in general form. Probably both *C. limax* W. B. Wright and *C. fallax* W. B. Wright are present, but many variations occur and in the material available it has not been possible to name many individuals. Shells of this type have been known for some time from the Lenisulcata Zone of South Wales, where they are frequently better preserved but where there is likewise an extremely wide range of variation.[1]

Anthracomya

In the non-marine lamellibranch band six feet above the Soft Bed Coal occurs a species of *Anthracomya* which appears to be quite distinct from *Anthracomya lenisulcata* Trueman and *A. prisca* Trueman which are known from near horizons. This shell

[1] Ware, W. D., and A. E. Trueman, 'Additions to the Fauna of the Coal Measures of South Wales,' *Proc. S. Wales Inst. Eng.*, vol. xlviii, 1932, figs. 3a and 3d.

is only represented at present by one incomplete specimen, which is much more tumid than the above-named species, and in which no trace of sulcation can be seen; the lower border is gently rounded, but not greatly inclined to the hinge margin.

Naiadites

Naiadites flexuosa Dix and Trueman occurs commonly in the higher part of the Lower Coal Measures but it has not been observed in Yorkshire below the level of the Hard Bed Coal. The most frequent species in the lower measures ranging up to an horizon 133 ft. above the Hard Bed Band Coal is more oblique (*i.e.* with a smaller angle α and a wider angle β)[1] than *Naiadites flexuosa*; the upper posterior border is usually straight or only very feebly sinuous, and the anterior lobe is frequently distinct. So far as the present material shows, this species is less variable than many species of *Naiadites*.

Summary of Progress of the Geological Survey and the Museum of Practical Geology for the Year 1933, Part II.

ERRATUM.

Page 47 paragraph entitled "The Marine Fossils"
line 10 *should read*:—

may be only of varietal importance. *Edmondia josepha* was described by de Koninck in 1842[2] as transversely-ovate, ornamented with numerous transverse striae and with a lanceolate lunule. The type came from the Carboniferous Limestone of Visé. It was further described by de Koninck in 1885[3] with slightly fuller details. Dr. Wheelton Hind greatly amplified the description in 1899[4] and mentions, in addition to the fine concentric lines at equal intervals, that the species has, here and there, irregular, broad and very shallow concentric sulci, and that there is much variation. He records the species from both the Lower and the Upper Limestone

[1] Dix, E., and A. E. Trueman, 'Some Observations on the genus *Naiadites*,' *Ann. Mag. Nat. Hist.*, Ser. 10, vol. ix, 1932, p. 3.
[2] Hind, W., 'A Monograph of the British Carboniferous Lamellibranchiata.' vol. i, *Palaeont. Soc.*, 1899.
[3] Hind, W., *op. cit.*, pl. xxxiii, figs. 10-13, not 14.
[4] de Koninck, L., 'Description des Animaux Fossiles qui se trouvent dans le Terrain Carbonifère de Belgique,' Liége, 1842, p. 68, pl. i, fig. 5.
[5] de Koninck, L., 'Faune du Calcaire Carbonifère de la Belgique, Cinquième Partie, Lamellibranches,' *Ann. Mus. Roy. Hist. Nat. Belg.*, tome xi, p. 30, pl. xi, figs. 30-31.
[6] Hind, W., *op. cit.*, p. 295.

many horizons in the Lower Coal Measures of Yorkshire. It is greatly to be regretted that the shells are in many cases badly preserved and are too incomplete to yield satisfactory types on which to base new species. Some of them resemble species which have been named by Dr. W. B. Wright, but it is rarely possible to make a definite identification, for the shells usually represent variants which differ to some extent from the types of those species.

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[illegible] *C. limax* W. B. Wright and *C. fallax* W. B. Wright are present, but many variations occur and in the material available it has not been possible to name many individuals. Shells of this type have been known for some time from the Lenisulcata Zone of South Wales, where they are frequently better preserved but where there is likewise an extremely wide range of variation.[1]

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[1] Ware, W. D., and A. E. Trueman, 'Additions to the Fauna of the Coal Measures of South Wales,' *Proc. S. Wales Inst. Eng.*, vol. xlviii, 1932, figs. 3a and 3d.

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2. The Marine Fossils

BY

J. Wilfrid Jackson, D.Sc., F.G.S.

Dr. D. A. Wray has submitted for verification a number of marine lamellibranchs from the above boring. Some of the specimens are, unfortunately, rather poorly preserved, but a species of *Edmondia* from the base of the Lower Coal Measures is of some interest. It seems to be distinct from most of the Lower Carboniferous species figured and described by Dr. Wheelton Hind,[2] and may turn out to be a new form. In general outline it closely resembles *Edmondia josepha* de Koninck, as figured by Hind,[3] but appears to differ in possessing a coarser ornament. This, however, may turn out to be a new form. In general outline it closely resembled by de Koninck in 1842[4] as transversely-ovate, ornamented with numerous transverse striae and with a lanceolate lunule. The type came from the Carboniferous Limestone of Visé. It was further described by de Koninck in 1885[5] with slightly fuller details. Dr. Wheelton Hind greatly amplified the description in 1899[6] and mentions, in addition to the fine concentric lines at equal intervals, that the species has, here and there, irregular, broad and very shallow concentric sulci, and that there is much variation. He records the species from both the Lower and the Upper Limestone

[1] Dix, E., and A. E. Trueman, 'Some Observations on the genus *Naiadites*,' *Ann. Mag. Nat. Hist.*, Ser. 10, vol. ix, 1932, p. 3.

[2] Hind, W., 'A Monograph of the British Carboniferous Lamellibranchiata.' vol. i, *Palaeont. Soc.*, 1899.

[3] Hind, W., *op. cit.*, pl. xxxiii, figs. 10-13, not 14.

[4] de Koninck, L., 'Description des Animaux Fossiles qui se trouvent dans le Terrain Carbonifère de Belgique,' Liége, 1842, p. 68, pl. i, fig. 5.

[5] de Koninck, L., 'Faune du Calcaire Carbonifère de la Belgique, Cinquième Partie, Lamellibranches,' *Ann. Mus. Roy. Hist, Nat. Belg.*, tome xi, p. 30, pl. xi, figs. 30-31.

[6] Hind, W., *op. cit.*, p. 295.

Series of Scotland, as well as from the Calciferous Sandstone Series of Fife, and from the Carboniferous Limestone of counties Limerick and Tyrone.

Until further specimens are available and comparisons made with examples resembling *Edmondia josepha* from Millstone Grit horizons,[1] I propose to refer to the Huddersfield specimens as *Edmondia* aff. *josepha* de Koninck. As seen in the figures, natural size (Plate IV, figs. 13, 14), the shells are oval and obliquely produced towards the postero-ventral part and the outline passes in a continuous curvature round the anterior, ventral and posterior margins. The surface is ornamented with fairly strong concentric rugae, close-set anteriorly and becoming wider apart posteriorly towards the lower margin: fine lines of growth are visible between the rugae. The interior is unknown. The horizon of this form is: Lower Coal Measures (Marine Band overlying the Pot Clay Coal). The specimens are numbered Bb.397. Bb.399-400B, 57138-9. On the same piece of shale as 57139 is a single valve of a *Myalina*, perhaps *M. compressa* Hind (Plate IV, fig. 14). Other species from the same marine band are *Gastrioceras subcrenatum* (Schlotheim MS.) C. Schmidt and allies; *Anthracoceras arcuatilobum* (Ludwig), *Pterinopecten papyraceus* (J. Sowerby) and *Posidonomya gibsoni* (Salter). *Lingula mytiloides* J. Sowerby was also found.

Shells extremely like the form under discussion have been recorded from continental localities at approximately the same level. A shell figured in 1930 as *Edmondia arcuata* (Phill.) by Dr. G. Delépine[2] from the Belgian Coal Measures (Mine No. 10; Grisoeil) at 1,150 metres, does not appear to me to agree well with Phillips' species. Judging from the illustration it seems to differ in shape, and the ornament is more strongly curved. It agrees closely with a specimen figured in 1912 by R. von Klebelsberg,[3] also ascribed to *Edmondia arcuata* (Phill.) and coming from the Marine Horizon V in the Theresa Shaft in Polish-Ostrau. Both the above shells resemble the *Edmondia* aff. *josepha* from the Huddersfield boring.

Hans Wehrli, in 1931[4] figured two examples of *Edmondia* as *E. arcuata* from marine horizons in the mines of Kaiserstuhl II and Kurl, near Dortmund (Horizon: Westphalian A, Upper Magerkohle: Girondelle 8). These figures seem to agree with Phillips' species. The shells were associated with *Lingula mytiloides* Sow. and other forms, including, it is stated, young examples of *Posidonomya becheri* (Bronn). The latter may be *P. gibsoni* (Salter).

The other forms submitted by Dr. Wray are as follows:—

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[1] Some were collected by the officers of the Geological Survey, S.W. of Marsden, Yorks. (Horizon: R2, mut. α=gracile).

[2] Delépine, G., *in* de Dorlodot J., and G. Delépine, 'Faune marine du Terrain Houiller de la Belgique; Deuxième Partie, Descriptions des Fossiles marins,' *Mem. de l'Inst. Géol. de l'Univ. de Louvain*, tome vi, fasc. 1, 1930, p. 89, pl. vi, fig. 27.

[3] Klebelsberg, R. von., 'Die marine Fauna der Ostrauer Schichten,' *Jahr. der K. K. geol. Reichsanstalt*, Bd. lxii, 1912, p. 493, pl. xxi, fig. 3.

[4] Wehrli, H., 'Die Fauna der westfälischen Stufen A und B der Bochumer Mulde zwischen Dortmund und Kamen (Westfalen),' *Palaeontographica*, Bd. lxxiv, 1931, pl. xxi, figs. 4-5.

Overlying the Middle Band Coal.—Specimens Bb.389-396. *Lingula mytiloides* J. Sowerby, and very young examples of *Posidonomya* probably *P. gibsoni* (Salter).

Second Marine Band 15 feet above Halifax Hard Bed Coal.—Specimens Bb.383-388. *Posidoniella* aff. *multirugata* Jackson (young examples).

Marine Band immediately overlying the 36-Yards or Hard Bed Band Coal—Specimens Bb.375-382. *Pterinopecten* aff. *papyraceus* (J. Sowerby) and one example of *Posidonomya gibsoni* (Salter). The only observations I can make with regard to the *Pterinopecten* are that, judging from the rather imperfect specimens, the posterior margin swings out, the concentric growth-lines are extremely fine, and the posterior notch under the hinge-line is still faintly visible and traceable in the growth-lines. In some examples of *Pterinopecten* from a higher horizon (Middle Coal Measures: Horizon of the Gin and Mansfield Marine Bands) the posterior notch seems to have disappeared entirely. The latter require further study.

Marine Band 52 feet above the 36-Yards or Hard Bed Band Coal.—Specimens Bb.368-374. *Pterinopecten* aff. *papyraceus* (J. Sowerby). These are badly preserved, being in some cases mere shadows.

Explanation of Plate IV

All specimens figured were collected from the boring for water at Messrs. Jarmain's, Minerva Mills, Kirkheaton, near Huddersfield. The figures are of natural size; figures 1-12 are from photographs by Mr. T. C. Marchant and figures 13-14 by Dr. J. W. Jackson. The specimens are all preserved in the collection of the Geological Survey in London; their register numbers are quoted in brackets.

Fig. 1. *Carbonicola sp.* In shales 133 feet above 36-Yards or Hard Bed Band Coal; depth 195 ft. [57126]

Fig. 2. *Naiadites flexuosa* Dix and Trueman. In shales 87 feet above Upper Band Coal; depth 84 ft. [57127]

Fig. 3. *Anthracomya lenisulcata* Trueman. In shales 70 feet above Hard Bed Coal; depth 367 ft. [57128]

Fig. 4. *Carbonicola sp.* (cf. *C. limax* W. B. Wright). In shales 70 feet above Hard Bed Coal; depth 367 ft. [57129]

Fig. 5. *Carbonicola sp.* (cf. *C. limax* W. B. Wright). In shales 67 feet above Hard Bed Coal; depth 370 ft. [57130]

Fig. 6. *Carbonicola* aff. *recta* Trueman. In shales 20 feet above Soft Bed Coal; depth 502 ft. [57131]

Fig. 7. *Carbonicola* aff. *haberghamensis* W. B. Wright. In shales 18 feet above the Soft Bed Coal; depth 504 ft. [57132]

Fig. 8. *Carbonicola sp.* (cf. *C. obliqua* W. B. Wright). In shales 27 feet above Soft Bed Coal; depth 494 ft. [57133]

Fig. 9. *Carbonicola* aff. *recta* Trueman. In shales 18 feet above Soft Bed Coal; depth 504 ft. [57134]

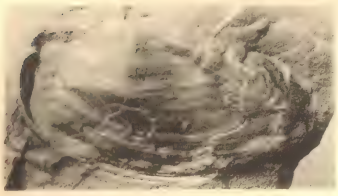
Fig. 10. *Carbonicola* aff. *recta* Trueman. In shales 18 feet above Soft Bed Coal; depth 504 ft. [57135]

Fig. 11. *Carbonicola* cf. *pseudacuta* Trueman. In shales 6 feet above Soft Bed Coal; depth 514 ft. [57136]

Fig. 12. *Carbonicola sp.* (see p. 39). In shales 20 feet above Soft Bed Coal; depth 502 ft. [57137]

Fig. 13. *Edmondia* aff. *josepha* de Koninck. At base of marine band overlying Pot Clay Coal; depth 641 ft. [57138]

Fig. 14. *Edmondia* aff. *josepha* de Koninck and *Myalina* cf. *compressa* Hind. At base of marine band overlying Pot Clay Coal; depth 641 ft. [57139]



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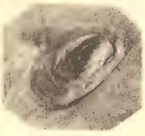

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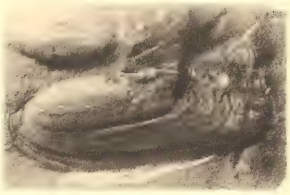

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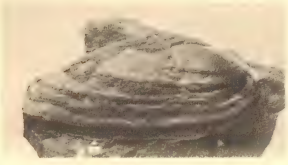

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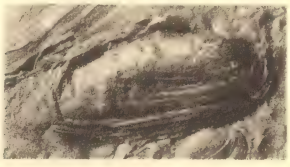

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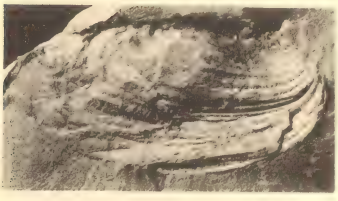

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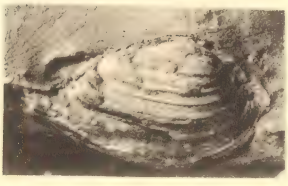

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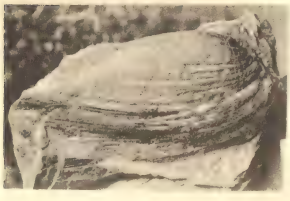

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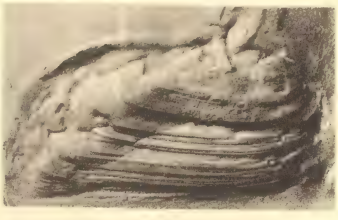
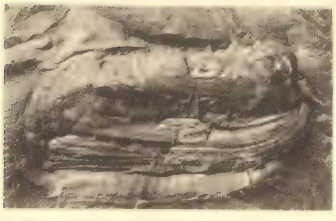
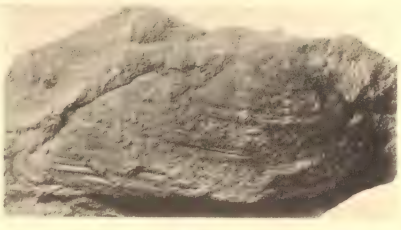


9



10



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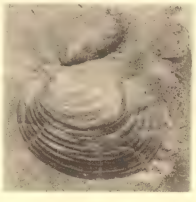

14

LAMELLIBRANCHS FROM THE LOWER COAL MEASURES OF YORKSHIRE.

V.—THE STRATIGRAPHICAL DISTRIBUTION OF BRITISH COAL MEASURE PLANT INCRUSTATIONS

BY

R. CROOKALL, D.Sc., PH.D.

INTRODUCTION

IN 1894, the late Dr. R. Kidston[1] published a complete list of the British Carboniferous plant-incrustations then known. Owing to his subsequent researches, and to those of the late Dr. E. A. N. Arber, the list has long been out of date. Not only does it contain certain inaccuracies, but the number of known species has since been more than doubled.

When his great Monograph on the Fossil Plants of the Carboniferous Rocks of Great Britain[2] should have been completed, it was Kidston's intention to publish a revised account of the Carboniferous floras. By great misfortune the Monograph was scarcely half completed at the time of his death.

The writer[3] has previously dealt with the Lower Carboniferous species, and the list of Coal Measure plants known at the present day is given in the succeeding pages.

Three factors are employed in comparing the fossil floras of the various divisions of the Coal Measures: (1) the occurrence of certain assemblages of species, (2) the frequency of individual forms composing the assemblages and (3) the absence of other assemblages.

Although Kidston and Arber repeatedly stressed the importance of taking into account the frequency of occurrence, their tables, in which the presence of a species was usually shown by a cross, provided no clue to the factor. Kidston[4] felt this to be a defect, for he observed, " The lists given in the tables showing the distribution of the fossil plants in the Carboniferous Rocks of Britain do not bring out this relative proportion of the species in the different series," and he provided a diagrammatic representation of a few of the more widely extended types. Similarly, in his account of the South Wales Coalfield[5] he observed, " In the form

[1] Kidston, R., ' On the Various Divisions of British Carboniferous Rocks as Determined by their Fossil Flora,' *Proc. Roy. Phys. Soc. Edin.*, vol. xii, 1894, pp. 238-257.

[2] Kidston, R., ' Fossil Plants of the Carboniferous Rocks of Great Britain' (*Mem. Geol. Surv.*) Palaeontology, vol. ii, 1923-1925. It is intended to resume the publication of this work as soon as possible.

[3] Crookall, R., ' The Stratigraphical Distribution of British Lower Carboniferous Plants,' Summary of Progress for 1931—Part II, (*Mem. Geol. Surv.*), 1932, pp.70—104.

[4] Kidston, R., *op. cit.*, 1894, op. 232.

[5] Kidston, R., ' On the Fossil Flora of the South Wales Coalfield,' *Trans. Roy. Soc. Edin.*, vol. xxxvii, 1894, pp. 565-614.

EX BIBL. UNIV. EDINBURGEN.

in which the tables are drawn up all the records appear of equal value, it having been found difficult to introduce a form of tabulation which would indicate the frequency or rarity of the recorded species." In the lists of species here given the writer has, in part, overcome the difficulty by means of numbers, thus: 1-2=very rare; 3-4=fairly rare; 5-7=fairly common; 8-10=very common. R=Radstockian Stage; S=Staffordian Stage; Y=Yorkian Stage; L=Lanarkian Stage.

The species in Kidston's original table were arranged systematically. For convenience of reference they are here placed in alphabetical order, the systematic position being shown in the Provisional Synopsis of Genera on pp. 54-57.

As some Coal Measure plants vary in the frequency of their occurrence in different coalfields, an adequate treatment of the distribution of species must be of a dual nature. A general treatment, such as that here given, must be supplemented by detailed accounts of the individual coalfields. The latter are to be found in the numerous papers on the coalfields and in the Memoirs of the Geological Survey. Certain aspects of the study of Coal Measure plants which have been discussed elsewhere by the writer are briefly reviewed below.

Nomenclature of the Coal Measures[1, 2]

Kidston originally adopted the classification of the Coal Measures used by Phillips, who divided the formation into Lower, Middle and Upper Coal Measures. These terms were criticised as liable to cause confusion. He therefore substituted for them the terms Lanarkian, Westphalian and Radstockian Series respectively, while the Transition Coal Measures he designated the Staffordian Series. This classification is still employed, though the term 'Series' is now replaced by 'Stage.' The Radstockian Stage was divided by Kidston into a lower and an upper group—the Farrington (=Keele) and the Radstock Groups. He further endeavoured to correlate, on floral evidence, the Staffordian Stage in various coalfields with the sub-divisions established in North Staffordshire by Dr. Walcot Gibson (*i.e.*, with the Blackband, Etruria Marl and Newcastle-under-Lyme Groups), but Wheelton Hind, and subsequently Dr. Emily Dix,[3] showed that such correlation was unsound. Finally, Kidston's term 'Westphalian' has been superseded by Professor W. W. Watts's 'Yorkian.'

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[1] Crookall, R., 'The Supposed 'Lanarkian' in Shropshire,' *The Naturalist*, 1932, pp. 37-40; 71-74.

[2] Crookall, R., 'Coal Measures Terminology,' *ibid.*, pp. 111-114; 137-140; 175-176.

[3] Dix, E., 'The Flora of the Upper Portion of the Coal Measures of North Staffordshire,' *Quart. Journ. Geol. Soc.*, vol. lxxxvii, 1931, p. 160.

The British Coal Measures therefore comprise:

RADSTOCKIAN STAGE { Radstock Group; Farrington (=Keele) Group
STAFFORDIAN STAGE
YORKIAN STAGE { Upper Yorkian; Lower Yorkian
LANARKIAN STAGE (including, in some areas, part of the Millstone Grit).

The base of the Radstockian Stage in Somerset is at the Farrington Series of coals and is probably the Hughes Vein of South Wales. The base of the Staffordian Stage in North Staffordshire has been drawn by Dr. Dix at just below the Chalky Mine. In South Staffordshire it is at the top of the Hamstead and Sandwell Park Marine Band, and in South Wales at the No. 3 Rhondda Seam of Glamorganshire and the Lower Pinchin Seam of the Merthyr area. In Lancashire it appears to be about the Bradford Four Foot Mine and in Yorkshire at the Shafton Marine Band.[1] The base of the Yorkian in Yorkshire is taken at the Better Bed and in Lancashire at the Arley Mine. In Scotland it is at the Mill or Auchingane Coal of Stirlingshire and its equivalents.

CHIEF ZONAL SPECIES

The Lanarkian Stage is mainly recognised by the occurrence of *Sphenopteris hoeninghausi, Neuropteris schlehani* and *Mariopteris acuta.* Of rarer occurrence are *Sphenopteris baeumleri* and *S. hülseni,* and although *Lepidophloios acerosus, Sigillaria elegans* and *Cordaites principalis* may occur with greater or less frequency, they are less helpful, being also known from the overlying Yorkian. Though some of the plants of the Lower Yorkian occur intermingled with the above named species (e.g. *Neuropteris gigantea, Alethopteris lonchitica*) they are, in general, markedly less frequent in the lower (Lanarkian) division, and a large number of other Yorkian forms are unrecorded from Lanarkian horizons. The diagnostic species of the Upper Yorkian are either extremely rare or absent.

The Lower Yorkian shows a great development of *Alethopteris lonchitica* and *Neuropteris gigantea,* while *N. obliqua,* though also attaining its maximum numbers in the division, is less characteristic. Only occasional examples of Lanarkian species (*Sphenopteris hoeninghausi* and *Neuropteris schlehani* in particular) are met with, and this in the lower beds.

The Upper Yorkian contains no Lanarkian plants. Here *Neuropteris tenuifolia, N. pseudogigantea* and *Sphenophyllum*

[1] According to Dr. D. A. Wray ('The Major Subdivisions of the Coal Measures in Yorkshire,' Summary of Progress for 1931, Part II, (*Mem. Geol. Surv.*), 1932, pp. 56-59). Mr. James Walton, however, is proposing a different line of division.

myriophyllum are exceedingly common, while *Lonchopteris rugosa*, though rare, is confined to the division. *Neuropteris grangeri, N. microphylla, Sigillaria elongata, S. rugosa, S. scutellata* and other species are at their maximum frequency. *Sphenophyllum majus* occurs in the Upper Yorkian (and passes up into the Staffordian) but is not found in the Lower Yorkian. *Alethopteris davreuxi* also appears to be characteristic of the division. Many other plants combine to make the very rich flora of the Yorkian Stage, but most are less characteristic and, by themselves, yield correlative results of less precision.

The Staffordian flora is a ' mixed ' one, consisting of both Yorkian and Radstockian species. Certain Radstockian forms (especially certain Pecopterids) are rarely if ever met with, however, in the Staffordian, while the same is true of many Yorkian plants. Moreover, the Staffordian is characterised by the frequence of *Linopteris münsteri* and *L. obliqua*. Other species which occur more or less frequently in the division are *Sphenopteris neuropteroides, Neuropteris tenuifolia* (in the basal beds), *N. ovata, N. flexuosa, N. scheuchzeri, N. pseudogigantea, Alethopteris serli, Mariopteris latifolia, M. nervosa, Sphenopteris striata, Sphenophyllum majus* and *S. emarginatum*.

The Radstockian Stage is mainly recognised by the abundance of the Cyatheites - Pecopterids—*Acitheca polymorpha, Asterotheca arborescens, A. cyathea, A. oreopteridia, Ptychocarpus unitus*, etc. *Alethopteris serli* occurs very commonly, as do *Neuropteris ovata, N. flexuosa, N. macrophylla, N. rarinervis* and *N. scheuchzeri*. *Odontopteris lindleyana*, though rarer, is characteristic. Other Radstockian plants are: *Lepidodendron wortheni, Sigillaria cumulata, Sphenophyllum emarginatum, Annularia stellata, A. sphenophylloides, Sphenopteris macilenta, S. neuropteroides, Poacordaites microstachys* and *Cordaites angulosostriatus*. The upper (Radstock) Group of this Stage contains many more examples of the Cyatheites-Pecopterids than does the lower (Farrington or Keele) Group.

PROVISIONAL SYNOPSIS OF GENERA

FUNGI—	Excipulites *Goeppert*, 1836
	Hysterites *Unger*, 1841
BRYOPHYTA—	Hapaticites *Walton*, 1925
FILICALES & PTERIDOSPERMEAE—	Adiantites *Schimper*, 1869
(1) leaves, Group 1. (Sphenopterideae)[1]	Alloiopteris *Potonié*, 1902
	Boweria *Kidston*, 1911
	Corynepteris *Baily*, 1860
	Coseleya *Kidston*, 1914
	Crossotheca *Zeiller*, 1883
	Cyclotheca *Kidston*, 1888
	Diplotmema *Stur*, 1877
	Eremopteris *Schimper*, 1869
	Hymenophyllites *Goeppert*, 1841
	Hymenotheca *Potonié*, 1890
	Macrosphenopteris *Kidston*, 1888
	Margaritopteris *Gothan*, 1913
	Mariopteris *Zeiller*, 1879
	Myriotheca *Zeiller*, 1883
	Oligocarpia *Goeppert*, 1841
	Palaeopteridium *Kidston*, 1923
	Radstockia *Kidston*, 1923
	Renaultia *Zeiller*, 1883
	Rhacopteris *Schimper*, 1869
	Rhodea *Presl*, 1838
	Senftenbergia *Corda*, 1845
	Sphenopteris *Brongniart*, 1822
	Sphyropteris *Stur*, 1883
	Telangium *Benson*, 1904
	Unatheca *Kidston*, 1891
	Urnatopteris *Kidston*, 1884
	Zeilleria *Kidston*, 1884
Group II. (Pecopterideae)	Acitheca *Schimper*, 1879
	Asterotheca *Presl*, 1845
	Dactylotheca *Zeiller*, 1883
	Dicksonites *Sterzel*, 1883
	Eupecopteris *Gothan*, 1921, (*Kidston*), 1925
	Pecopteris *Brongniart*, 1822 (*Kidston*), 1925
	Ptychocarpus *Weiss*, 1869
Group III. (Alethopterideae)	Alethopteris *Sternberg*, 1820
	Desmopteris *Stur*, 1883
	Lonchopteris *Brongniart*, 1828

[1] These and the succeeding groups are for convenience only and do not necessarily imply that the included genera are related.

Group IV. (Neuropterideae)	Callipteridium *Weiss*, 1870 Dolerophyllum *Saporta*, 1878 Linopteris *Presl*, 1838 Neuropteris *Brongnairt*, 1822 Odontopteris *Brongniart*, 1828
FILICALES & PTERIDOSPERMEAE INCERTAE SEDIS—(1) foliage	Aphlebia *Presl*, 1838 Cyclopteris *Brongniart*, 1828 Spiropteris *Schimper*, 1869
(2) Tree-fern stems	Caulopteris *Lindley and Hutton*, 1832 Megaphyton *Artis*, 1825 Ptychopteris *Corda*, 1845
EQUISETALES—(a) herbaceous	Equisetites *Sternberg*, 1833
(b) arborescent (1) stems	Calamites *Suckow*, 1820
(2) leafy branches and leaves	Annularia *Sternberg*, 1820 Asterophyllites *Brongniart*, 1828
(3) fructifications	Calamostachys *Schimper*, 1869 Cingularia *Weiss*, 1876 Macrostachya *Schimper*, 1869 Palaeostachya *Weiss*, 1884 Paracalamostachys *Weiss*, 1884 Stachannularia *Weiss*, 1876 Volkmannia *Sternberg*, 1820
SPHENOPHYLLALES— (1) leaves & stems	Sphenophyllum *Brongniart*, 1822
(2) fructifications	Sphenophyllostachys *Solms-Laubach*, 1881
LYCOPODIALES— (a) herbaceous	Lycopodites *Goldenberg*, 1855 Selaginellites *Zeiller*, 1906
(b) arborescent (1) stems	Asolanus *Wood*, 1860 Bothrodendron *Lindley and Hutton*, 1833 Halonia *Lindley and Hutton*, 1833 Lepidodendron *Sternberg*, 1820 Lyginodendron *Gourlie*, 1843 Lepidophloios *Sternberg*, 1825 Pinakodendron *Weiss*, 1893 Sigillaria *Brongniart*, 1822
(2) leaves & bracts	Lepidophyllum *Brongniart*, 1828 Sigillariophyllum *Grand 'Eury*, 1890

	(3) fructifications, etc.	Lepidocarpon *Scott*, 1901 Lepidocystis *Lesquereux*, 1880 Lepidostrobus *Brongniart*, 1828 Lycopod Macrospores Sigillariostrobus *Schimper*, 1870.
	(4) rhizophores & rootlets	Stigmaria *Brongniart*, 1822 Stigmariopsis *Grand 'Eury*, 1877
CORDAITALES—	(1) leaves	Cordaites *Unger*, 1850 Dorycordaites *Grand 'Eury*, 1877 Poacordaites *Grand 'Eury*, 1877
	(2) stems	Artisia *Sternberg*, 1825
	(3) fructifications	Cordaianthus *Grand 'Eury*, 1877
DETACHED ? MICROSPOROPHYLLS—		Whittleseya *Newberry*, 1854
DETACHED ? BRACTS—		Microspermum *Arber*, 1914
UNASSIGNED GYMNOSPERMOUS SEEDS—		Carpolithus *Linnaeus*, 1768 Cordaicarpus *Geinitz*, 1862 Gentopsis *Renault*, 1884 Hexagonocarpus *Renault*, 1888 Holcosperma *Nathorst*, 1914 Lagenospermum *Nathorst*, 1914 Neuropterocarpus *Grand 'Eury*, 1904 Polypterocarpus *Grand 'Eury*, 1877 Rhabdocarpus *Berger*, 1848 Samaropsis *Goeppert*, 1864 Trigonocarpus *Brongniart*, 1828
CONIFERALES INCERTAE SEDIS— (leafy branches)		Walchia *Sternberg*, 1826
CYCADOPHYTA—		Pterophyllum *Brongniart*, 1825
INCERTAE SEDIS—(leaves)—		Dicranophyllum *Grand 'Eury*, 1875 Psygmophyllum *Schimper*, 1870
	—(roots)—	Myriophyllites *Artis*, 1825 Pinnularia *Lindley and Hutton*, 1834

LIST OF SPECIES

Acitheca polymorpha (*Brongniart*). R (5) ; S (1)

Adiantites adiantoides (*Lindley & Hutton*). Y (1) ; L (2)
,, bondi *Kidston*. Y (1)
,, sessilis *Potonié* Y (?1)
,, tenellus *Kidston* L (1)
,, wardi *Kidston*. Y (1)

Alethopteris aquilina *Brongniart* (non *Schlotheim*). R (?4) ; S (?3) ; Y (?1)
,, costei *Zeiller*. S (?1)
,, davreuxi (*Brongniart*). R (?2) ; S (?1) ; Y (?4)
,, decurrens (*Artis*). S (1) ; Y (7) ; L (2)
,, grandini *Kidston* (non *Brongniart*). R (4) ; S (2) ; Y (1)
,, lonchitica (*Schlotheim*). S (1) ; Y (10) ; L (4)
,, oblongata (*Sternberg*). R (1) ; S (1)
,, pontica *Zeiller*. R (1)
,, serli *Kidston* (? *Brongniart*). R (10) ; S (6) ; Y (3) ; L (1)
,, valida *Boulay*. Y (3) ; L (1)
,, radstockensis *Kidston*. R (1)
,, serrula (*Lesquereux*). S (1)

Annularia dubia (*Sternberg*). Y (4) ; L (2)
,, galioides (*Lindley & Hutton*). Y (3)
,, ingens *Goode*. Y (1)
,, radiata *Brongniart*. R (1) ; S (3) ; Y (9) ; L (9)
,, sphenophylloides (*Zenker*). R (7) ; S (3) ; Y (1)
,, huttoni *Lebour*. Y (1)
,, spicata (*Gutbier*). Y (1)
,, stellata (*Schlotheim*). R (10) ; S (3) ; Y (1)

Aphlebia acanthoides *Zeiller*. S (?1)
,, anomala (*Brongniart*). Y (2)
,, crispa (*Gutbier*). R (3) ; S (1) ; Y (?1) ; L (?1)
,, gigantea (*Goeppert*). Y (1)
,, goldenbergi *Weiss*. R (1)
,, linearis (*Gutbier*). Y (10)
,, membranacea *Lesquereux*. Y (1)
,, spinosa *Lesquereux*. R (1) ; Y (1)

Artisia approximata (*Brongniart*). R (1) ; S (1) ; Y (2) ; L (1)
,, transversa (*Artis*). S (1) ; Y (1) ; L (1)

Asolanus camptotaenia *Wood*. R (2) ; S (2) ; Y (2)

Asterophyllites charaeformis (*Sternberg*). S (1) ; Y (6) ; L (1)
,, dumasi *Zeiller*. S (1) ; Y (2)
,, equisetiformis (*Schlotheim*). R (8) ; S (5) ; Y (8) ; L (6)
,, grandis (*Sternberg*). S (1) ; Y (3) ; L (2)
,, jubata (*Lindley & Hutton*). Y (3)
,, longifolius (*Sternberg*). S (1) ; Y (2) ; L (1)
,, lycopodioides *Zeiller*. L (?1)

Asterotheca abbreviata (*Brongniart*). R (8) ; S (?1)
,, arborescens (*Schlotheim*). R (6) ; S (3)
,, candolleana (*Brongniart*). R (1) ; S (1)
,, crenulata (*Brongniart*). R (1) ; S (1)
,, cyathea (*Schlotheim*). R (6) ; S (3)
,, daubreei *Zeiller*. R (3)
,, hemitelioides (*Brongniart*). R (1) ; S (1)
,, lamuriana (*Heer*). R (1)
,, lepidorachis (*Brongniart*). R (1) ; S (?1)
,, miltoni (*Artis*). S (1) ; Y (10)
,, oreopteridia *Kidston* (? *Schlotheim*). R (7) ; S (2)

Aulacopteris vulgaris *Grand'Eury*. Y (1)

Bothrodendron minutifolium (*Boulay*). R (?1) ; S (1) ; Y (6) ; L (1)
,, punctatum *Lindley & Hutton*. Y (4)
Boweria minor *Kidston*. Y (3)
,, schatzlarensis *Kidston*. Y (3)

Calamites britannicus (*Weiss*). Y (3)
,, brittsi White (*Kidston & Jongmans* emend). Y (1)
,, brongniarti *Sternberg*. Y (1)
,, cannockensis *Arber*. Y (1)
,, carinatus *Sternberg*. R (4) ; S(4) ; Y (8) ; L (2)
,, cisti *Brongniart*. R (2) ; S (1) ; Y (6) ; L (1)
,, dictyoderma *Kidston & Jongmans*. Y (1)
,, discifer *Weiss*. Y (2)
,, germarianus *Goeppert*. Y (2)
,, goepperti *Ettingshausen*. S (?1) ; Y (5)
,, jubatus (*Lindley & Hutton*). Y (2) ; L (?1)
,, multiramis Weiss (*Kidston & Jongmans* emend). R (1)
,, ohlsbachensis *Sterzel*. Y (2)
,, paleaceus *Stur*. S (1) ; Y (3)
,, pseudogermarianus *Kidston & Jongmans*. Y (1)
,, sachsei *Stur* (pars). R (1) ; S (1) ; Y (5) ; L (2)
,, schützei *Stur*. Y (1)
,, schützeiformis *Kidston & Jongmans forma* typicus R (1) ; S (1) ; Y (2)
,, schützeiformis *Kidston & Jongmans forma* intermedius. R (1) ; Y (1)
,, schützeiformis *Kidston & Jongmans forma* waldenburgensis *Kidston*. R (2) ; S (3) ; Y (9)
,, semicircularis *Weiss*. Y (3)
,, steinhaueri *Sternberg*. Y (1)
,, suckowi *Brongniart*. R (6) ; S (6) ; Y (10); L (10)
,, undulatus *Sternberg*. R (1) ; S (2) ; Y (8) ; L (6)
,, verticillatus *Lindley & Hutton*. Y (3)
,, wedekindi *Weiss*. Y (1)
Calamostachys longifolia *Weiss*. Y (1)
,, ludwigi (*Carruthers*). Y (2)
,, ? nana *Weiss*. Y (?1)
,, northumbriana (*Kidston*). Y (2)
,, paniculata *Weiss*. Y (2)
,, ramosa *Weiss*. Y (2)
,, roehli *Kidston* (? *Stur*). Y (3)
,, tuberculata (*Sternberg*). R (3) ; S (2)
,, typica *Schimper*. Y (2)
Callipteridium gigas *Kidston* (? *Gutbier*). R (1)
Carpolithus areolatus (*Boulay*). S (1) ; Y (1)
,, ellipticus *Sternberg*. Y (1)
,, inflatus *Lesquereux*. Y (4)
,, membranaceus *Goeppert*. R (1) ; S (1) ; Y (6)
,, minimus *Sternberg*. Y (1)
,, ovoideus *Goeppert & Berger*. R (2) ; S (1) ; Y (2)
,, perpusillus *Lesquereux*. R (2) ; Y (6) ; L (2)
,, regularis *Sternberg*. Y (1)
,, sphaericus *Schenk*. Y (2)
,, wildi *Kidston*. Y (2)
Caulopteris anglica *Kidston*. R (1)
,, arberi *Kidston* MS. R (1)
,, cyclostigma (*Lesquereux*). R (1)
,, peltigera (*Brongniart*). R (1)
,, primaeva *Lindley & Hutton*. R (1)

Cingularia cantrilli *Kidston*. Y (1)
,, typica *Weiss*. Y (1)
Cordaianthus dubius *Grand'Eury*. S (1)
,, pitcairniae (*Lindley & Hutton*). Y (8); L (1)
,, subacutus *Grand'Eury*. Y (1)
,, volkmanni (*Ettingshausen*). S (1); Y (4)
Cordaicarpus congruens *Grand'Eury*. Y (1)
,, cordai (*Geinitz*). S (1); Y (3)
,, crassus (*Lesquereux*). Y (1)
,, gutbieri (*Geinitz*). R (1); S (1); Y (1)
,, lindleyi (*Carruthers*). R (1); S (1); Y (1)
Cordaicladus approximatus *Renault*. Y (1)
Cordaites angulosostriatus *Kidston* (? *Grand'Eury*). R (9); S (4)
,, borassifolius (*Sternberg*). R (1); S (2); Y (6)
,, principalis (*Germar*). S (3); Y (9); L (6)
Cornucarpus arberi *Crookall* (*Kidston* MS.). R (1); S (5); Y (1)
Cornynepteris coralloides (*Gutbier*). S (1); Y (6)
,, sternbergi (*Ettingshausen*). S (1); Y (4)
Coseleya barkeri *Kidston*. Y (3)
,, glomerata *Kidston*. Y (3)
Crossotheca boulayi *Zeiller*. S (2); Y (1)
,, communis (*Lesquereux*). Y (2)
,, crépini *Zeiller*. S (1); Y (3)
,, hughesiana *Kidston*. Y (3)
,, kidstoni *Crookall*. Y (5)
,, pinnatfida (*Gutbier*). R (3); S (1)
,, sagittata (*Lesquereux*). R (1)
,, schatzlarensis (*Stur*). Y (3)
Cyclopteris reinformis *Brongniart*. S (?1)
,, trichomanoides *Sternberg*. Y (1)
Cyclostigma macconochiei (*Kidston*). Y (1)
Cyclotheca biseriata *Kidston*. Y (1)

Dactylotheca parallela *Kidston*. Y (1)
,, plumosa (*Artis*). S (2); Y (10); L (1)
Desmopteris longifolia *Presl*. R (2); S (1)
Dicksonites pluckeneti (*Schlotheim*). R (3)
Dicranophyllum anglicum *Kidston*. Y (1)
Dictyocalamites burri *Arber*. S (1)
Diplotmema coemansi (*Andrae*). S (1)
,, duponti *Stur*. Y (3)
,, furcatum (*Brongniart*). Y (7); L (2)
,, geniculatum (*Germar & Kaulfuss*). R (1)
,, intermedium (*Ettingshausen*). Y (1)
,, schatzlarense *Stur*. Y (1)
,, sturi (*Gothan*). Y (3)
,, zeilleri *Stur*. R (?1)
,, zobeli (*Goeppert*). Y (1)
Dolerophyllum pseudopeltatum *Grand'Eury*. S (1); Y (5)
Dorycordaites palmaeformis (*Goeppert*). R (1); S (2); Y (5)

Equisetites hemingwayi (*Kidston*). Y (6)
,, rugosus *Schimper*. S (1)
Eremopteris artemisaefolia (*Sternberg*). Y (6); L (?)
,, zamioides (*Bertrand*). Y (1)

Eupecopteris bucklandi (*Brongniart*). R (2) ; S (1)
,, camertonensis *Kidston*. R (3) ; S (1)
,, cisti (*Brongniart*). R (2) ; S (1)
,, dentata (*Brongniart*). R (7) ; S (3)
,, fletti *Kidston*. R (3)
,, minor *Kidston*. Y (1)
,, pteroides (*Brongniart*). R (1)
,, villosa (*Brongniart*) R (1)
,, volkmanni (*Sauveur*). S (1) ; Y (16)
Excipulites callipteridis (*Schimper*). R (2)
,, neesi *Goeppert*. R (2) ; Y (1)

Gnetopsis anglica *Kidston*. Y (3)
,, hexagona *Delpape & Carpentier*. Y (1)

Halonia tortuosa *Lindley & Hutton*. Y (4)
Hepaticites kidstoni *Walton*. Y (1)
Hepaticites langi *Walton*. Y (1)
,, lobatus *Walton*. Y (1)
,, metzgerioides *Walton*. Y (1)
,, willsi *Walton*. S (1)
Hexagonocarpus hookeri *Kidston*. Y (1)
Holcosperma elongatum (*Kidston*). Y (6)
,, giganteum (*Grand'Eury*). R (1)
,, mammillatum (*Lesquereux*). S (3)
,, mentzelianum (*Goeppert & Berger*). S (1)
,, multistriatum (*Presl*). R (1) ; S (1)
,, rugosum (*Arber*). R (?1) ; Y (1)
,, sulcatum (*Presl*). R (1) ; S (1) ; Y (?)
Huttonia spicata *Sternberg*. Y (1)
Hymenophyllites bronni (*Gutbier*). Y (1)
,, quadridactylites (*Gutbier*). Y (1)
Hymenotheca acuta *Kidston*. Y (1)
Hysterites cordaitis *Grand'Eury*. R (1)

Knorria selloni *Lindley & Hutton*. Y (1)

Lagenospermum kidstoni (*Arber*). Y (1)
,, oblongum (*Kidston*). Y (1)
,, parvulum *Kidston*. Y (1)
,, urceolaris (*Kidston*). Y (1)
Lepidocarpon westphalicum *Kidston*. Y (1)
Lepidocystis fraxiniformis *Lesquereux*. S (1) ; Y (1)
,, vesicularis *Lesquereux*. R (1) ; Y (2)
Lepidodendron aculeatum *Sternberg*. R (4) ; S (4) ; Y (9) ; L (5)
,, acutum (*Presl*). S (3) ; Y (5)
,, dichotomum *Zeiller*. R (2) ; S (6) ; Y (4)
,, distans *Lesquereux*. S (1) ; Y (?1) ; L (1)
, fusiforme (*Corda*). R (1) ; S (1) ; Y (3)
,, gaudryi *Renault*. Y (4)
,, jaraczweski *Zeiller*. S (?1) ; Y (4)
,, lanceolatum *Lesquereux*. R (7) ; S (5) ; Y (? 1)
,, landsburgi *Kidston*. Y (2)
,, lycopodioides *Kidston* (? *Sternberg*). S (3) ; Y (8) ; L (2)

Lepidodendron obovatum *Sternberg*. S (2) ; Y (9) ; L (4)
,, ophiurus *Brongniart*. S (1) ; Y (10) ; L (3)
,, peachi *Kidston*. Y (1) ; L (1)
,, rhombicum (*Presl*). R (1)
,, rimosum *Sternberg*. S (2) ; Y (4) ; L (2)
,, simile *Kidston*. S (? 2) ; Y (? 8) ; L (?)
,, wedekindi *Weiss*. S (1) ; Y (2)
,, wortheni *Lesquereux*. R (7) ; S (4) ; Y (?)
Lepidophloios acerosus (*Lindley & Hutton*). S (1) ; Y (6) ; L (8)
,, laricinus *Sternberg*. S (1) ; Y (6) ; L (2)
,, macrolepidotus *Goldenburg*. Y (1)
Lepidophyllum acuminatum *Lesquereux*. R (? 1) ; S (2) ; Y (2)
,, brevifolium *Lesquereux*. R (2) ; S (2) ; Y (1)
,, intermedium *Lindley & Hutton*. S (1) ; Y (2)
,, major *Brongniart*. R (5) ; S (2) ; Y (1)
,, morissianum *Lesquereux*. S (1) ; Y (2)
,, triangulare *Zeiller*. R (2) ; S (1) ; Y (8)
Lepidostrobus anthemis (*Koenig*). S (2) ; Y (7)
,, geinitzi *Schimper*. Y (1) ; L (1)
,, goldenbergi *Schimper*. Y (? 1)
,, goodei *Jongmans*. R (2) ; S (1) ; Y (4)
,, hastatus *Lesquereux*. S (1)
,, incertus *Lesquereux*. S (1)
,, jacksoni *Arber*. Y (1)
,, lanceolatus (*Lindley & Hutton*). R (? 1) ; Y (2) ; Y (7) ; L (7)
,, moyseyi *Arber*. S (1) ; Y (1)
,, spinosus *Kidston*. R (1) ; Y (1)
,, squarrosus *Kidston*. Y (1) ; L (?)
,, variabilis *Lindley & Hutton*. S (2) ; Y (2) ; L (2)
Linopteris major *Goode*. (Y 1)
,, münsteri (*Eichwald*). R (1) ; S (8) ; Y (1)
,, neuropteroides (*Gutbier*). S (? 1) ; Y (2)
,, obliqua (*Bunbury*). S (8) ; Y (2)
Lonchopteris bricei *Brongniart*. Y (4)
,, eschweileriana *Andrae*. Y (3)
,, rugosa *Brongniart*. Y (3)
Lycopodites meeki *Lesquereux*. Y (1)
,, pendulus *Lesquereux*. Y (1)

Macrosphenopteris lindsaeoides *Kidston*. R (1)
Macrostachya infundibuliformis (*Brongniart*). R (3) ; S (2)
Margaritopteris conwayi (*Lindley & Hutton*). S (1) ; Y (3)
Mariopteris acuta (*Brongniart*). Y (3) ; L (8)
,, beneckei *Huth*. Y (1)
,, coarctata (*Stur*). Y (4)
,, daviesi *Kidston*. R (1) ; S (1) ; Y (1)
,, dernoncourti *Zeiller*. Y (1)
,, hirta (*Stur*). S (1) ; Y (1) ; L (1)
,, jacquoti *Zeiller*. Y (2)
,, latifolia (*Brongniart*) *Zeiller*. S (5) ; Y (2)
,, lobatifolia *Kidston*. Y (1)
,, loshi (*Brongniart*). Y (1)
,, muricata *Kidston* (? *Schlotheim*). S (1) ; Y (3) ; L (1)
,, nervosa (*Brongniart*). R (? 1) ; Y (10) ; L (7)
,, nervosa *var.* oblongata *Brongniart*. Y (2) ; L (1)
,, nobilis (*Achepohl*). S (1)
,, obovata *Kidston*. Y (1)
,, plumosa *Kidston*. R (1)
,, sauveuri (*Brongniart*). S (1) ; Y (4)
,, soubeirani *Zeiller*. Y (1)

Megaphyton anomalum *Grand'Eury.* Y (1)
,, approximatum *Lindley & Hutton.* Y (2)
,, elongatum *Kidston.* (R (1)
,, frondosum *Artis.* R (1) ; Y (2)
,, giganteum *Goldenburg.* Y (1)
,, goldenbergi *Weiss.* Y (1)
,, souichi *Zeiller.* Y (1)

Microspermum samaroides (*Carpentier*). Y (1)

Myriophyllites gracilis (*Artis*). Y (4)

Myriotheca anglica *Kidston.* Y (1) ; L (1)

Neuropteris blissi *Lesquereux.* S (1) ; Y (3)
,, bockingiana (*Weiss*). Y (1)
,, boghdanowiczi (*Zalessky*). Y (2)
,, callosa *Jongmans & Gothan.* Y (3)
,, camptophylla *Jongmans & Gothan.* S (? 1) ; Y (1)
,, carpentieri *Kidston.* Y (1)
,, crenulata *Brongniart.* Y (2)
,, dentata *Lesquereux.* Y (1)
,, fimbriata *Lesquereux.* R (5) ; S (2)
,, flexuosa *Sternberg.* R (10) ; S (7)
,, flexuosa *var.* rotundifolia *Brongniart.* R (1)
,, gibbosa *Lesquereux.* S (1)
,, gigantea *Sternberg.* S (3) ; Y (10) ; L (3)
,, grangeri *Kidston* (? *Brongniart*). S (1) ; Y (6)
,, heterophylla *Brongniart.* R (1) ; S (2) ; Y (10) ; L (4)
,, kossmanni *Arber* (non *Potonié*). Y (1)
,, macrophylla *Brongniart.* R (9) ; S (3)
,, microphylla *Brongniart.* S (1) ; Y (6)
,, obliqua (*Brongniart*). S (1) ; Y (8)
,, obliqua *var.* impar *Gothan.* Y (1)
,, osmundae (*Artis*). R (? 1) ; Y (3)
,, ovata *Hofmann.* R (9) ; S (8) ; Y (1)
,, plicata *Sternberg.* Y (2)
,, pseudogigantea *Potonié.* S (? 3) ; Y (? 8)
,, rarinervis *Bunbury.* R (9) ; S (8) ; Y (3)
,, cf. raymondi *Zeiller.* S (1)
,, (Cyclopteris) reniformis *Brongniart.* S (? 1)
,, scheuchzeri *Hofmann.* R (10) ; S (10) ; Y (4)
,, schlehani *Stur.* Y (2) ; L (8)
,, tenuifolia (*Schlotheim*). S (6) ; Y (10)
,, thymifolia *Sternberg.* R (1) ; S (? 1)

Neuropterocarpus subtunicatus (*Grand'Eury*). Y (1)

Odontopteris lindleyana *Sternberg.* R (4) ; S (2)

Oligocarpia brongniarti *Stur.* Y (1)
,, gutbieri *Goeppert.* S (1) ; Y (3)

Omphalophloios anglicus (*Sternberg*). R (4)

Palaeostachya ettingshauseni *Kidston.* S (?) ; Y (6)

Paracalamostachys striata *Weiss.* Y (? 1)
,, williamsoniana *Weiss.* Y (? 1) ; L (1)

Pecopteris armasi *Zeiller*. R (1)
,, aspera *Brongniart*. L (2)
,, bioti *Brongniart*. Y (1)
,, hepaticiformis *Kidston*. Y (? 1)
,, integra (*Andrae*). R (1)
,, richardsoni *White*. S (? 1)
Pinnularia capillacea *Lindley & Hutton*. R (6); S (6); Y (7); L (3)
Poacordaites microstachys (*Goldenberg*). R (2); S (1)
Polypterocarpus anglicus (*Kidston*). Y (1)
,, johnsoni (*Kidston*). Y (1)
,, ornatus (*Kidston*). S (1); Y (3)
Psilotites unilateralis *Kidston*. Y (1); L (1)
Psygmophyllum flabellatum (*Lindley & Hutton*). Y (1)
Pterophyllum sp. S (1)
Ptychocarpus unitus (*Brongniart*). R (8); S (3)

Radstockia sphenopteroides (*Kidston*). R (1); S (1)
Renaultia chaerophylloides (*Brongniart*). S (1); Y (3)
,, crepini (*Stur*). Y (1)
,, germanica *Potonié*. L (1)
,, gracilis (*Brongniart*). Y (3); L (2)
,, hemingwayi *Kidston*. S (1)
,, rotundifolia (*Andrae*). S (1); Y (5)
Rhabdocarpus conicus *Renault*. S (1)
,, insignis *Lesquereux*. R (1)
,, lillieanus *Arber*. S (1)
,, oliveri *Kidston*. Y (1)
,, tunicatus *Goeppert & Berger*. R (1)
Rhacopteris dubia (*Lindley & Hutton*). Y (1)
,, moyseyi (*Arber*). Y (1)
Rhodea eltringhami *Kidston*. Y (1)
,, gutbieri (*Ettingshausen*). Y (1)
,, sparsa *Kidston*. L (1)
,, subpetiolata (*Potonié*). Y (1)

Samaropsis acuta (*Lindley & Hutton*). Y (5); L (?)
,, emarginata *Goeppert & Berger*. Y (2)
,, pseudofluitans *Kidston*. R (? 1); S (? 1); Y (4)
,, marginata (*Artis*). Y (4)
,, meachemi (*Kidston*). Y (2)
,, quadriovata *Kidston*. Y (2)
,, reniformis (*Geinitz*). S (1)
,, subacutus *Grand'Eury*. Y (1)
,, zonulata (*Lesquereux*). L (? 1)
Samarospermum moravicum (*Helmhacker*). Y (1)
Selaginellites gutbieri (*Goeppert*). R (1)
Senftenbergia ophiodermatica (*Goeppert*). Y (2)
Sigillaria alternans (*Sternberg*). R (1); S (1); Y (2); L (1)
,, antoninae *Zalessky*. Y (1)
,, barbata *Weiss*. Y (1)
,, barbata *var.* datheana *Koehne*. Y (1)
,, boblayi *Brongniart*. S (1); Y (4)
,, brardi *Brongniart*. R (3); S (1); Y (1)
,, candollei *Brongniart*. Y (2)
,, cordiformis *Kidston*. Y (3)
,, cordigera *Zeiller*. S (1); Y (1)
,, coriacea *Kidston*. Y (1)

Sigillaria cumulata *Weiss.* R (6)
,, davreuxi *Brongniart.* Y (4)
,, deutschiana *Brongniart.* S (1) ; Y (4)
,, diploderma *Corda.* Y (3)
,, discophora (*Koenig*). R (1) ; S (1) ; Y (8) ; L (2)
,, distans *Sauveur.* Y (2)
,, elegans (? *Sternberg*) *Brongniart.* Y (3) ; L (8)
,, elegans *var.* brongniartiana *Weiss.* L (1)
,, elegans *var.* communis *Weiss.* Y (1) ; L (1)
,, elegans *var.* regularis *Weiss.* L (1)
,, elegans *var.* tenuimarginata *Weiss.* L (1)
,, elongata *Brongniart.* S (1) ; Y (7)
,, euxina *Zeiller.* Y (1)
,, feistmanteli *Geinitz.* Y (1)
,, germanica *Weiss.* R (? 1) ; S (? 1) ; L (1)
,, ichthyolepis (*Sternberg*). S (1) ; Y (2)
,, incerta *Kidston.* L (2)
,, kidstoni *Crookall.* S (1)
,, kinletensis *Arber.* Y (1)
,, laevigata *Brongniart.* R (5) ; S (1) ; Y (8)
,, mammillaris *Brongniart.* S (2); Y (8) ; L (2)
,, mammillaris *var.* abbreviata *Weiss.* Y (2)
,, mammillaris *var.* dournaisi *Brongniart.* Y (3) ; L (? 1)
,, maurici *Grand 'Eury.* S (1)
,, mc'murtriei *Kidston.* R (2)
,, meachemi *Arber.* Y (1)
,, micaudi *Zeiller.* Y (2)
,, nodosa (*Bowman*). Y (?)
,, nortonensis *Crookall.* R (1)
,, nudicaulis *Boulay.* S (1) ; Y (1)
,, orbicularis *Brongniart.* R (1) ; Y (2)
,, ovalis *Lesquereux.* Y (1)
,, ovata *Sauveur.* R (? 1) ; S (1) ; Y (8)
,, polleriana *Brongniart.* Y (3) ; L (1)
,, polyploca *Boulay.* S (1) ; Y (5)
,, principis *Weiss.* S (1) ; Y (6)
,, pringlei *Kidston.* Y (1)
,, punctirugosa *Kidston.* Y (1)
,, pyriformis *Brongniart.* Y (? 1)
,, reniformis *Brongniart.* R (? 1) ; S (1) ; Y (7)
,, reticulata *Lesquereux.* Y (3)
,, rugosa *Brongniart.* S (1) ; Y (8)
,, sauli *Brongniart.* S (1) ; Y (4)
,, sauveuri *Zeiller.* Y (2)
,, schlotheimi *Brongniart.* S (2) ; Y (3)
,, scutellata *Brongniart.* S (2) ; Y (8) ; L (3)
,, scutiformis *Zalessky* (pars). Y (3)
,, semipulvinata *Kidston.* Y (3)
,, sol *Kidston.* Y (1)
,, strivelensis *Kidston.* L (1)
,, tenuis *Achepohl.* S (? 1) ; Y (? 3)
,, tessellata *Brongniart* (*Steinhauer*). R (1) ; S (3) ; Y (10) ; L (2)
,, tessellata *var.* alveolaris *Brongniart* (non *Sternberg*). Y (1)
,, transversalis *Brongniart.* Y (3)
,, transversalis *var.* sparsifolia *Boulay.* S (1) ; Y (1)
,, trigona (*Sternberg*). S (1) ; Y (4)
,, utschneideri *Brongniart.* Y (2)
,, voltzi *Brongniart.* Y (34)
,, vulgaris (*Artis*). Y (3)
,, walchi *Sauveur.* S (1) ; Y (3)

Sigillariophyllum bicarinatum (*Lindley & Hutton*). R (6); S (4); Y (8); L (2)

Sigillariostrobus ciliatus *Kidston*. Y (5)
,, rhombibracteatus *Kidston*. Y (3)

Sphenophyllum amplum *Kidston pro sp*. L. (4)
,, angustifolium (*Germar*). R (? 1)
,, cuneifolium (*Sternberg*). S (2); Y (10); L (3)
,, emarginatum *Brongniart*. R (10); S (7); Y (1)
,, fasciculatum (*Lesquereux*). S (? 1)
,, kidstoni *Hemingway*. Y (3)
,, longifolium *Germar*. R (1); S (1)
,, majus *Bronn*. R (1); S (3); Y (4)
,, myriophyllum *Crépin*. S (1); Y (5)
,, oblongifolium (*Germar & Kaulfuss*). S (? 1); Y (? 1)
,, trichomatosum *Stur*. R (1); S (1); Y (5)
,, wingfieldense *Hemingway*. Y (2)

Sphenopteris alata *Brongniart*. R (3); S (1)
,, amoenaeformis *Kidston*. Y (1); L (? 1)
,, andreana *Roehl*. Y (1)
,, arberi *Kidston*. Y (1)
,, baeumleri *Andrae*. L (3)
,, bella *Stur*. S (1); Y (3)
,, cantiana *Kidston*. Y (1)
,, coriacea *Marrat*. Y (1)
,, corifolia *Kidston*. Y (1)
,, delavali *Zeiller*. Y (1)
,, deltiformis *Kidston*. Y (1)
,, derbiensis *Kidston*. Y (1)
,, dilatata *Lindley & Hutton*. S (1); Y (6)
,, dixoni *Kidston*. Y (1)
,, elegantiformis (*Stur*). Y (2)
,, fentoniana *Kidston*. Y (1)
,, flabellifolia *Kidston*. Y (1); L (1)
,, flexuosissima (*Stur*). Y (1)
,, footneri *Marrat*. Y (4)
,, formosa *Gutbier*. L (? 1)
,, hoeninghausi *Brongniart*. Y (2); L (8)
,, hülseni *Gothan*. L (1)
,, incurva *Kidston*. Y (1)
,, kayi *Arber*. S (? 1); Y (1)
,, kilimi *Kidston*. Y (1)
,, lanarkiana *Kidston*. Y (1); L (? 1)
,, laurenti *Andrae*. S (1); Y (6); L (2)
,, macilenta *Lindley & Hutton*. R (7); Y (1)
,, marrati *Kidston*. S (1); Y (3)
,, mixta *Schimper*. Y (1)
,, moyseyi *Kidston*. Y (1)
,, neuropteroides (*Boulay*). R (7); S (3)
,, nummularia *Gutbier*. Y (4); L (1)
,, obtusiloba *Brongniart*. S (? 1)
,, ovatifolia *Lillie*. S (1)
,, pecopteroides *Kidston*. R (1); S (1)
,, polyphylla *Lindley & Hutton*. Y (1)
,, pseudofurcata *Kidston*. Y (1)
,, quadriloba *Kidston*. Y (1)
,, repanda (*Lindley & Hutton*). Y (1)
,, sancti-felicis (*Stur*). Y (2)
,, sauveuri *Crépin*. S (1); Y (7)
,, (? Renaultia) schatzlarensis (*Stur*). Y (6); L (1)

Sphenopteris schillingsi *Andrae.* Y (3)
,, schwerini (*Stur*). Y (3)
,, selbyensis *Kidston.* Y (1)
,, sewardi *Kidston.* R (1)
,, souichi *Zeiller.* Y (1)
,, spiniformis *Kidston.* Y (6) ; L (1)
,, spinosa *Goeppert.* S (1) ; Y (1)
,, spinulosa (*Stur*). Y (2)
,, stipulata (*Gutbier*). Y (1)
,, stonehousei *Kidston.* Y (3)
,, striata *Gothan.* S (4) ; Y (9) ; L (4)
,, tenuissima *Presl.* S (1) ; Y (2)
,, trifoliolata (*Artis*). Y (7)
,, trigonophylla *Behrend.* Y (2)
,, truncata *Kidston.* Y (1)
,, vernoni *Kidston.* Y (3)
,, walteri *Stur.* Y (3)
,, westphalica (*Stur*). Y (1)
,, woodwardi *Kidston.* R (1)
Sphyropteris obliqua (*Marrat*). Y (3)
,, tomentosa ? *Stur.* Y (1)
Stachannularia calathifera *Weiss.* R (4) ; S (2)
Stigmaria ficoides (*Sternberg*). R (6) ; S (6) ; Y (10) ; L (7)
,, ficoides *var.* minor *Geinitz.* R (1) ; Y (1)
,, ficoides *var.* undulata *Goeppert.* S (1) ; Y (1) ; L (1)
,, minuta *Goeppert pro var.* R (? 1) ; S (1) ; Y (5) ; L (1)
,, reticulata *Goeppert pro var.* Y (4)
Stigmariopsis anglica *Kidston.* S (1) ; Y (5)
,, rimosa *Goldenberg.* S (1) ; Y (1)

Telangium digitatum *Kidston.* Y (1)
,, potieri ? (*Zeiller*). S (1)
Trigonocarpus candolleanus (*Unger* non *Heer*). Y (3)
,, dawesi (*Lindley & Hutton*). R (1)
,, moyseyi *Arber.* Y (1)
,, noeggerathi (*Sternberg*). R (4) ; S (2) ; Y (1)
,, oblongus *Lindley & Hutton.* Y (4)
,, ovatus *Lindley & Hutton.* Y (2) ; L (? 1)
,, parkinsoni *Brongniart.* S (1) ; Y (6)
,, schultzianus *Goepper & Berger.* L (2)

Unatheca oblonga *Kidston.* R (1)
Urnatopteris herbacea (*Boulay*). S (1)
,, tenella (*Brongniart*). Y (6) ; L (2)

Walchia imbricata *Schimper.* R (1) ; S (1)
,, piniformis (*Schlotheim*). R (1)
Whittleseya elegans *Newberry.* Y (1)
,, fertilis *Kidston.* Y (3)

Zeilleria avoldensis (*Stur*). S (1) ; Y (3)
,, delicatula (*Sternberg*). S (1) ; Y (4)
,, frenzli (*Stur*). Y (1)
,, hymenophylloides *Kidston.* Y (2) ; L (1)

VI.—ON A BORING FOR WATER AT STONEFOLD FARM, BERWICKSHIRE

BY

W. MANSON

with

PETROGRAPHICAL NOTES

BY

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Text-figure 1.

IN the autumn of 1930 a boring which proved to be of outstanding interest was completed at Stonefold farm, three miles south-east of Greenlaw, in Berwickshire. The bore was situated near the western gable of the farmhouse in order to obtain a convenient supply of water for domestic purposes. Permission to examine the cores and make detailed notes of the strata was kindly given by F. Caldwell, Esq., proprietor of Stonefold.

Stonefold and Greenlaw lie in the eastern part of one-inch map, Sheet 25, Scotland. The geological edition of this map, published in 1879 by the Geological Survey, shows the eastern half of the area to be mainly composed of rocks assigned to the Carboniferous and Old Red Sandstone formations, while the western portion is occupied by older rocks.

Stonefold is situated on the strip of Carboniferous rocks that extends from the northern boundary of the Sheet to as far south as Kelso, near the southern border of the map. These rocks form the narrowed extension of the Carboniferous basin of Lower Tweedside, and in the Kelso-Stonefold district they are separated from the sediments of the Upper Old Red Sandstone by a belt of basic lavas which have been long known to geologists as the "Kelso Traps." The interest of the Stonefold bore lies chiefly in the evidence which it has supplied bearing on the age of these lavas. On Sheet 25, to which reference has already been made, a lower horizon of the Kelso volcanic rocks has been placed in the Upper Old Red Sandstone while the main outcrop is included in the Calciferous Sandstone Series. In his 'Ancient Volcanoes of Great Britain' Geikie[1] described the volcanic rocks of Kelso and regarded them as constituting a portion of a great series of plateau eruptions which reached their maximum development in

[1] Geikie, Sir A., 'The Ancient Volcanoes of Great Britain,' 1897, vol. i, pp. 375-385.

Calciferous Sandstone times. He states that the Kelso lavas are "mainly interposed between the Upper Old Red Sandstone and the base of the Carboniferous System, which they thus serve to divide from each other. But their lowest sheets appear to be in some places intercalated in the Old Red Sandstone, so that their eruption probably began before the beginning of the Carboniferous period."

On the plate of comparative vertical sections at the end of their paper on the Canonbie Coalfield, Peach and Horne[1] have regarded the top of the lavas as marking the upper limit of the Upper Old Red Sandstone in Berwickshire and Northumberland.

The object of these notes is mainly to record the strata encountered in the bore, and to show, on lithological evidence, that the volcanic episode in the Stonefold area was brought to a close during the later stages of the deposition of the Cornstone Group of the Upper Old Red Sandstone.

Details of the Bore

A graphic section of the strata proved by the bore is shown in the accompanying diagram, Fig. 1.

After passing through two beds of boulder-clay interleaved by a bed of gravel the bore reached solid rock at a depth of 52 ft. and a good core, about 3 in. in diameter, was obtained of the strata encountered below this position. To the depth of 147 ft. the rocks consisted of thinly bedded greenish and grey arenaceous shales with a few thin beds of sandstone. In the next 46 ft. several bands of sandy cementstone were found associated with beds of grey calcareous sandstones and shales. These rocks passed downwards into a few feet of red and purplish coloured marly mudstones which overlay a band of grey cementstone 9 in. thick at 198 ft. from the surface. Below this cementstone a marked change in the character of the sediments was apparent, and to the depth of 237 ft. the strata were almost wholly composed of purplish, red and green mudstones containing nodular bands and ribs of white and pink cornstones. At 237 ft. 10 in. a bed of stratified ashy grit dominantly of detrital origin, 2 ft. 2 in. thick, was encountered. This rock was largely composed of somewhat rounded fragments of cornstone set in a red and green coloured calcareous matrix, the whole having the general appearance of bedded volcanic ash. For some 36 ft. below the bed of ashy grit the sediments were composed of red marls and mudstones resting on a bed of white nodular cornstone, 3 ft. 6 in. thick. The first lava was encountered soon after this cornstone was passed. It proved to be a green and grey coloured basalt having the top and base markedly vesicular. The lava was slightly over 6 ft. in thickness and the base was reached at the

[1] Peach, B. N., and J. Horne, 'The Canonbie Coalfield: its Geological Structure and Relations to the Carboniferous Rocks of the North of England and Central Scotland,' *Trans. Roy. Soc. Edin.*, vol. xl, 1905, pp. 835-877, and plate iv.

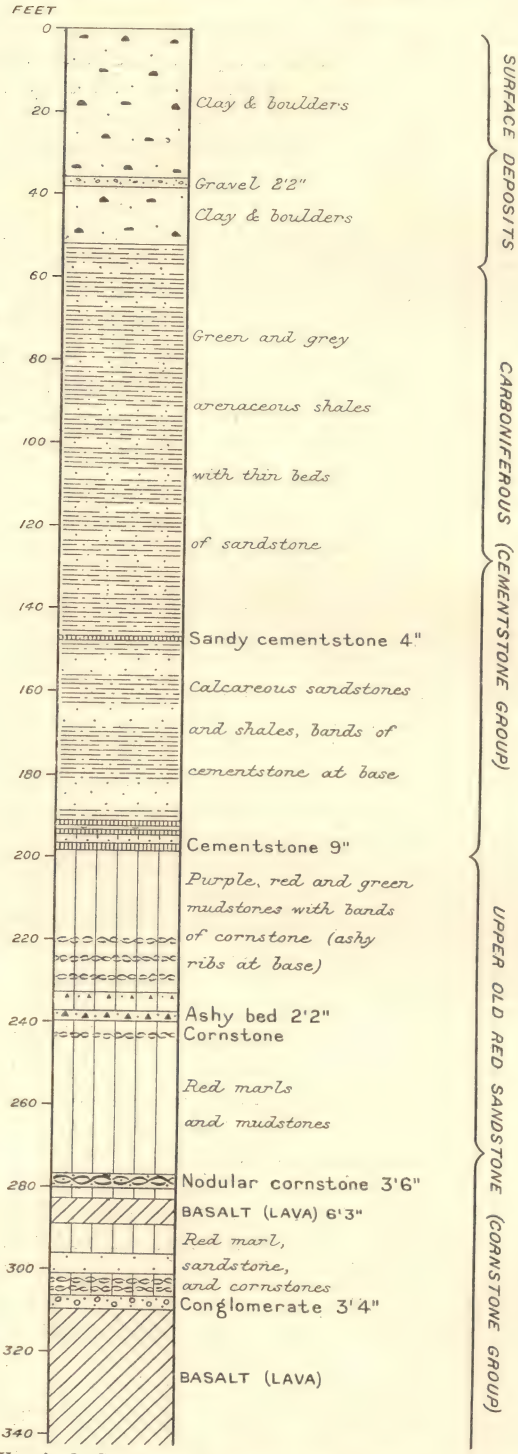

FIG. 1.—*Vertical Section of Boring at Stonefold, Berwickshire.*

depth of 289 ft. In the following 18 ft., beds of red marl, red sandstone, and red marl with bands of cornstone, overlay a bed of reddish conglomerate 3 ft. 4 in. thick. Pebbles in the conglomerate consisted mainly of purple and grey porphyritic and vesicular basalts. They were fairly well-rounded and bound together in a coarse, gritty and pebbly matrix.

The conglomerate rested directly on the second lava and although no irregularity was discernible in the cores at the junction of the two rocks it was noticed that the igneous rock was only sparingly vesicular and perhaps the upper portion of this flow was removed by denudation prior to the deposition of the conglomerate. The colouration of the lava was mainly green in the upper part and purple below. The lower part contained abundant vesicles of calcite and there was also present a fairly large fragment of a xenolith of hardened red sandstone. After cutting over 30 ft. of this lava the bore was stopped, but on taking into account the vesicular character of the lava the bore had probably reached a position not far from the base of the flow.

Conclusion

In reviewing the succession of rocks proved by the bore it is clear that the basal beds of the Carboniferous in the Stonefold or Greenlaw district consist of fairly typical strata of the Cementstone Group and that the base of the Carboniferous should be fixed at the depth of 198 ft. 3 in. in the bore (Fig. 1). Below this position the sedimentary strata are of such a nature as would warrant their inclusion in the Cornstone Group of the Upper Old Red Sandstone. In this district, therefore, as the ashy bed and top lava are interbedded with these sediments and cornstones, it seems reasonable to infer that the final phase of vulcanicity was brought to a close in Upper Old Red Sandstone times and before strata usually assigned to the Carboniferous formation were deposited. That still lower flows of lava occur in the Cornstone Group is borne out by the presence of interbedded cornstone at the outcrop of lavas further west.

Petrographical Notes

The rocks (S29715-17) collected from the Stonefold Water Bore at 240 ft. from the surface appear in hand specimen to be a coarse tuff or fine-grained agglomerate streaked with, and passing into, red marl with occasional small pebbles. The tuff is of a pale green and red colour and is composed of white, green, and a smaller number of purplish grains and fragments varying in size from small specks to pieces half a centimetre across. Under the microscope the constituents of the rock are mainly fragments of cornstone and grains of quartz. The larger cornstone fragments are angular with rounded corners, the medium sizes are

elliptical and the smaller are rounded. The material varies from a dense uniform cornstone to varieties with abundant angular quartz grains and rare plagioclase felspar. The quartz grains of the rock are well graded averaging .1 mm. diameter in one slice, .2 mm. in another. They are mostly subangular to subrounded but both angular and well-rounded millet-seed grains are present. Some show strain effects. Subordinate constituents include iron ore, which is abundant in one slice but absent in the others. The grains sometimes show crystal form but are generally nodular. A small number of rounded prisms of zircon occurs in the section which shows abundant iron ore. Microcline, usually angular or subangular and of the same dimensions as quartz, consistently forms a small proportion of the grains. Grains of calcite are seen in one slice, in which also are present some small composite grains consisting of not more than three individuals representing fragments of felspathic sandstone. The cement of the rocks varies in quantity and composition; in part it is largely opaque granular carbonate derived from the cornstone; or it may consist mainly of granular carbonates. As a rule it consists of cloudy carbonates, ferric oxides and silica (chalcedony). No igneous material has been observed in the thin sections though one contains a number of round and elliptical grains and rounded fragments of opaque limonitic material which may represent igneous lapilli or may perhaps be pisolitic grains.

The rock under examination is therefore dominantly of detrital origin since the mineral constituents show rounding and grading according to both size and specific gravity. The cornstone fragments on the other hand show no grading and show rounding only in the smaller pieces. These have either been derived locally or are pyroclastic fragments which have settled in water in which they have suffered only slight abrasion.

The top of the conglomerate at 307 ft. is mottled red and green in colour and has a rather marly matrix in which are set small lava pebbles; in its lower parts, however, it is a tough chocolate-coloured rock with purplish pebbles of lava which are larger and more numerous than in the upper portion. Some uncertainty was felt whether this bed should be regarded as a conglomerate or a resorted coarse tuff. Most of the pebbles appeared to be of lava of a type different from that immediately underlying the bed and a thin section of a pebble proved this to be the case. The section (S29721) shows a very highly decomposed andesite or basalt much finer in grain than the olivine-basalts described below, and possessing quite a different texture, for example the iron-ore is always granular and never exhibits the rod or hair form typical of these olivine-basalts. The bed is therefore probably neither a contemporaneous tuff nor a local conglomerate formed by erosion of the underlying basalt. As pointed out above, (p. 71), the absence of a vesicular top to the latter indicates a period of erosion prior to deposition of the conglomerate.

Five sections of igneous rock are available, three from a depth of 285 ft. (S29718-20) and two from 318 (S29723) and 342 ft. (S29724) respectively. All are of the same kind of decomposed olivine-basalt probably of Dalmeny type, and show the same type of alteration. They resemble the decomposed olivine-basalts of the Birrenswark Group. One specimen is richly vesicular while the other shows only a few small vesicles. In hand specimen they are grey or greenish grey rocks with abundant rusty ferrites. Thin sections show microphenocrysts of olivine (average diameter 1 mm.) pseudomorphed by iron ore and yellow or green iddingsite which in some cases is itself altering to ferric oxides. The groundmass consists of laths of felspar which can occasionally be recognised as labradorite with about 60 per cent An. There seems, however, to have been a general albitisation resulting in the change of the labradorite to oligoclase and on this is superimposed a further change to cryptocrystalline material which shows a low to moderate aggregate double refraction. This material appears to hold two components, one of low to very low double refraction and one of comparatively high double refraction. The latter is sometimes seen as minute shreds and is probably white mica. Tiny pseudomorphs of olivine in green iddingsite are sometimes seen but usually the form has been destroyed and the groundmass constituents other than the felspar consist of shapeless patches of iddingsite, limonitic material, brown carbonates, and iron ore. Rarely aggregates of brown carbonate and ore granules have a compact shape suggesting replacement of pyroxene. The habit of the iron ore is worth special mention as in all the slices it occurs predominantly as long rods or right-angled combinations of rods and hairs. Some sections show late introduction of chlorite, others of calcite and a little quartz.

VII.—THE CARBONIFEROUS ROCKS OF INNINMORE, MORVERN

BY

M. MACGREGOR, M.A., D.Sc., AND W. MANSON

Text-figure 1

THE object of the present communication is to place on record the results of a recent examination of the Carboniferous rocks of Inninmore Bay on the Sound of Mull. The writers were fortunate in being able to detect some plant-bearing horizons which had hitherto escaped notice and they also publish for the first time detailed descriptions of the natural sections available. For the sake of completeness it has been thought desirable to preface this account with a brief summary of previous work on the area.

1. INTRODUCTION

Inninmore Bay lies on the northern shores of the Sound of Mull, some 3 miles east-south-east of the entrance to Loch Aline.[1] The existence of an outlier of Carboniferous rocks at this locality was first demonstrated by Judd[2] and an account of them is given in the third of his series of classical papers on 'The Secondary Rocks of Scotland.'[3] Judd described the outcrop as "excessively small, extending only for a few hundreds of yards along the shore," and stated that "these remarkably isolated Carboniferous beds are exposed only in a series of tangle-covered reefs in front of the wild ravine of the Innimore of Ardtornish." The evidence he adduced for the age of the strata may be quoted in full. "These beds of the Innimore of Ardtornish consist of somewhat coarse white sandstones, and of fine-grained highly micaceous sandstones of a very dark tint, passing occasionally into shales. Both the coarse-grained and the fine-grained rocks are crowded with plant-remains, which in the former exist as hollow casts, and in the latter retain their carbonaceous matter. Occasional thin and imperfect seams of coal occur, and the agreement in physical characters of this most northern patch of Carboniferous strata with the strata of the same age in other parts of our islands is most complete and striking.

"Fortunately, too, the palaeontological evidence as to their position in the geological series is of the most satisfactory character. The plant-remains, though abundant, are seldom sufficiently well

[1] One-inch Geological Map of Scotland, Sheet 44; six-inch map Argyllshire 71.

[2] Judd, J. W., 'Existence of Carboniferous Rocks in the Highlands of Scotland,' *Geol. Mag.*, 1874, pp. 573-574.

[3] Judd, J. W., 'The Secondary Rocks of Scotland: Third Paper.—The Strata of the Western Coast and Islands,' *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv, pp. 684-686.

preserved for specific determination. Among the forms which I have been able to detect as occurring there are :—

Lepidodendron aculeatum, *Presl.*
Calamites Suckowii, *Brongn.*
Calamites Cistii, *Brongn.*
Sigillaria Saulii, *Brongn.*
Stigmaria.

The only specimen of *Lepidodendron* which I have been able to obtain is an example more than a foot in diameter. This and the species of *Calamites* afford the most satisfactory evidence concerning the age of the strata."

Judd concluded that the Carboniferous rocks at this locality " cannot exceed 40 or 50 feet in thickness." It is clear, however, that he was dealing only with the outcrops of arenaceous strata exposed on the foreshore to the west of Inninmore Cottage and did not include in the Carboniferous any of the strata seen in the streams descending from the high ground behind (see Fig. 1). In 1910, the district was surveyed on the six-inch scale for the Geological Survey by the late Dr. G. W. Lee and in the course of this work a collection of plant-remains was made from the shore-section 300 yds. west of Inninmore Cottage. Among these Dr. R. Kidston was able to identify the following species :—

Asterophyllites equisetiformis (*Schlotheim*)
Neuropteris gigantea *Sternberg*
Calamites suckowi *Brongniart*
Calamites cisti *Brongniart*
Calamites waldenburgensis *Stur*
Stigmaria ficoides (*Sternberg*)
Carpolithes sp.

"The first three on the list were represented by several specimens, while *Calamites waldenburgensis, Stigmaria* and the *Carpolithes* were represented by only one example each. None of these plants can be regarded as zonal forms, but as all are typical species of the ' Lanarkian Series,' and there is an entire absence of any species typically distinctive of the ' Westphalian Series '—above which horizon the beds cannot be placed—it is almost certain that the rocks which yielded these fossils belong to the ' Lanarkian Series.' "[1] At a later date (1914) Mr. Keir A. Campbell obtained Carboniferous plants from a band of lilac-coloured shale occurring in a stream-section at an altitude of about 100 ft.[2] Among these Dr. Kidston was able to determine the following forms :—

Asterophyllites charaeformis *Sternberg*
Neuropteris gigantea *Sternberg*
Samaropsis sp.

[1] Kidston, R., in ' Summary of Progress for 1910,' (*Mem. Geol. Surv.*), 1911, p. 28.
[2] See ' Pre-Tertiary Geology of Mull, Loch Aline and Oban,' (*Mem. Geol. Surv.*), 1925, p. 57.

This plant-bed is recorded[1] as occurring in the Quarry Burn but there seems little doubt that this is an error. The Quarry Burn is choked with debris and the plants were in all probability obtained from the burn situated 225 yds. to the east of it, in which the writers have been able to find plant-remains at four horizons (*see below*). Mr. Campbell's plant-bed would thus correspond to the lowest of these. The same observer also added the form *Artisia approximata* (Brongniart) to the list of specimens obtained from the shore-section west of Inninmore Cottage. These discoveries were incorporated by Dr. G. W. Lee[2] in his account of the Inninmore Carboniferous rocks in ' The Pre-Tertiary Geology of Mull, Loch Aline and Oban.' Dr. Lee, after summarising the available evidence, concluded " that at least 200 ft. of Carboniferous strata are exposed above sea-level near Inninmore Cottage; and it is quite possible that part of the beds still classed as Trias may really be Carboniferous."

2. Detailed Account

The Carboniferous rocks of Inninmore Bay occupy a narrow strip of country of about five square miles in extent, stretching from the Inninmore Fault westwards for a little over a mile (Fig. 1). They are overlain unconformably to the north by a thin development of Triassic and Lower Liassic strata, above which rise the precipitous Tertiary basalt cliffs of Glais Bheinn. So much of the ground is occupied by alluvial deposits or obscured by landslips and scree material that no definite estimate of the thickness of the Carboniferous rocks can be reached. They are certainly considerably thicker, however, than any estimate hitherto made. In the accompanying sketch-map (Fig. 1) of the district the most important sections are indicated by letters.

Section A.—The steep burn situated some 225 yds.[3] east of the Quarry Burn yields the most continuous and best exposed section of the Carboniferous sediments. Details[4] are given in the following table in which the more important beds with plant-remains are indicated by an asterisk :—

Section in stream to east of Quarry Burn

		Thickness Fms. Ft. In.	Depth Fms. Ft. In.
Trias (lower part)	Cornstone, white; forming sill of fall		
	Marls, red; with small scattered pebbles and pebbly layers	5 5 0	
	Breccia of angular fragments up to 2½ or 3 in. in a red matrix; variegated at top ... ... 6 ft. to	1 2 0	

[1] *Ibid.* pp. 57 and 66.
[2] *Ibid.* pp. 56-58.
[3] Measured along foot-path.
[4] This section was independently measured by Messrs. J. E. Richey and J. B. Simpson. Their estimates of thickness agree closely with those given in this paper.

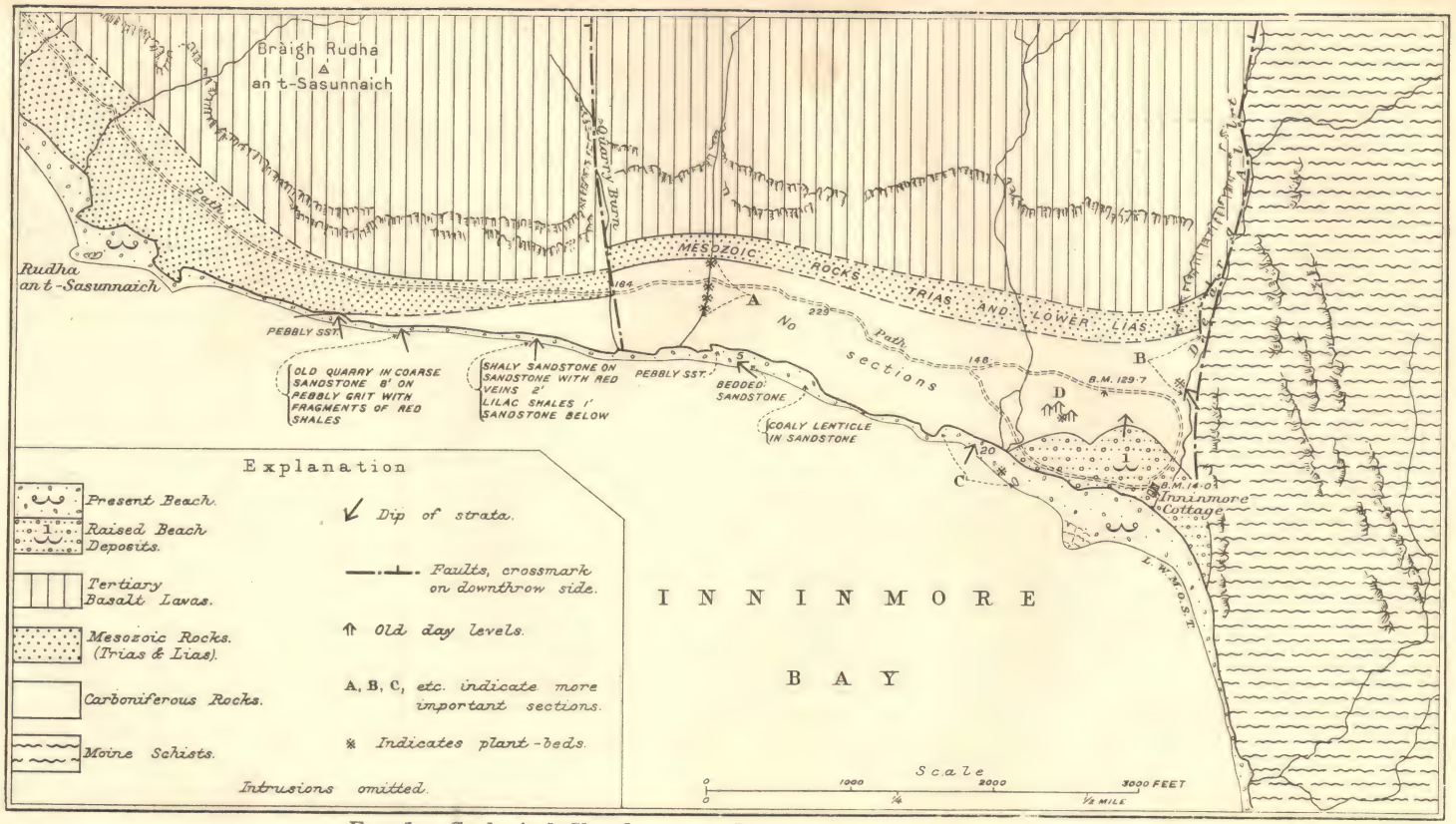

FIG. 1.—*Geological Sketch-map of Inninmore area* (after G. W. Lee).

Sandstone, hard, fine-grained; with irony nodules at base and weathered top	0	2	0	0	2	0
Sandstone, hard, false-bedded	0	1	0	0	3	0
Grit, yellowish; with scattered pebbles 2 ft. to	0	3	0	1	0	0
Fireclay, variegated, sandy; red iron-stone balls ... ... 1 ft. to	0	3	0	1	3	0
Sandstone, gritty; with occasional pebbles and irregular top	0	5	0	2	2	0
Sandstone, coarse; with pebbles and occasional clay galls	0	1	6	2	3	6
Sandstone, yellowish; layers of pebbles in lower half	1	4	3	4	1	9
Sandstone, with partings of purplish sandy shales containing a few branching plant-stems*	1	3	6	5	5	3
Sandstone, yellowish; with red irony nodules	1	1	0	7	0	3
Sandstone, massive; with pebbly layers 6 to 8 in. thick, especially in upper part about	5	3	0	12	3	3
Shales, sandy, micaceous (base of water-fall just above foot-bridge) 1 ft. to	0	1	6	12	4	9
Sandstone, yellowish; with irony concretions	0	5	9	13	4	6
Sandstone, yellowish, coarse; with lenticular patches of lilac shale and irony concretions; pebbly base 14 ft. to	2	3	0	16	1	6
Shales, sandy, variegated; with thin bed of dark-grey shale containing ribbed plant stems*	1	0	0	17	1	6
Sandstone, shaly	0	1	0	17	2	6
Sandstone, greenish, soft and shaly ...	0	1	6	17	4	0
Sandstone, hard	0	1	6	17	5	6
Shales, sandy; with carbonaceous patches	0	2	9	18	2	3
Sandstones flaggy, micaceous	0	1	0	18	3	3
Sandstone, hard; with irregular bands of lilac shale up to 3 in.; irony veins below	0	2	0	18	5	3
Shales, lilac-coloured	0	0	3	18	5	6
Sandstone, hard ... ... 3 in. to	0	0	9	19	0	3
Shales, lilac-coloured; plant stems* 2 in. to	0	0	5	19	0	8
Sandstone, yellowish; gritty and false-bedded below	0	4	0	19	4	8
Sandstone, coarse and pebbly; pebbles of purple shale and irony concretions at base	1	0	0	20	4	8
Sandstone, shaly; with layers of lilac shale	0	0	3	20	4	11
Sandstone, coarse; many pebbles of purple shale; dessication breccia ...	1	0	0	21	4	11
Sandstone, coarse; much kaolinitic material and pebbles of quartz up to 2 in.	0	4	0	22	2	11
Breccia of coarse grit and grey and lilac shales	0	1	6	22	4	5
Grit, hard; with clay galls	0	0	4	22	4	9
Grit, yellowish; with irregular layers of lilac shale	0	0	9	22	5	6

Shales, lilac-coloured; *Neuropteris*, etc.* 3 in. to	0	0	4	22	5	10
Grit, yellowish; with pockets of purple shale	0	1	3	23	1	1
Sandstone, pebbly	0	0	6	23	1	7
Sandstone, yellowish, false-bedded ...	0	2	0	23	3	7
Sandstone, coarse	2	1	0	25	4	7
Shales, lilac-coloured; traces of plant-stems	0	0	6	25	5	1
Sandstone, coarse; with patches of haematite below and irregular base ...	0	2	0	26	1	1
Sandstone, coarse, massive	2	5	0	29	0	1

It will be seen that plant-remains have been obtained on at least four horizons; it was probably from the lowest of these that Mr. Keir A. Campbell secured the specimens listed in an earlier paragraph (p. 75) and it was just above this horizon that Dr. Lee[1] tentatively placed the local base of the Trias. The additional evidence that the writers have been able to secure shows, however, that the Carboniferous rocks at this locality must be considerably thicker, and the Trias correspondingly thinner, than was previously thought to be the case. The dividing line between the Carboniferous and the Trias is now drawn just below the well-marked breccia which occurs in the stream-section 70 or 80 ft. above the foot-path. The reasons for the adoption of this line are:—

(a) The beds above the breccia and below the Lower Liassic limestones and shales can be definitely referred to the Trias. They consist of about 100 ft. of strata, comprising red marls with pebbly layers, cornstones with cherty bands, red marls with cornstone nodules, and subordinate red marly and gritty sandstones.

(b) The beds below the breccia, on the other hand, are markedly different in aspect and show a regular and unbroken[2] succession of mainly yellowish and often coarse or pebbly sandstones, with subordinate bands of shaly material and some fireclay. The flora listed from this section on page 83 was obtained from the three lowest plant-beds occurring at depths of approximately 17, 19 and 23 fathoms below the breccia. A few branching plant-stems were found about 6 fathoms below the breccia but were too poorly preserved for identification.

(c) The breccia consists for the most part of angular fragments of reddened psammitic Moine Schist, associated with pieces of granite and of vein-quartz. These are embedded in a red marly matrix, and similar rock-fragments occur, sometimes as layers, in the overlying thick beds of marl. The fragments appear to be of local rock-types.

(d) The coarser bands in the underlying sandstone contain, on the other hand, only pebbles of quartz; no schist or granite fragments have been observed.

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[1] 'Pre-Tertiary Geology of Mull, Loch Aline and Oban,' (*Mem. Geol. Surv.*), 1925, p. 66.
[2] A small fault crosses the stream immediately to the north of the foot-bridge.

(e) At the base of the breccia, red marl, often carrying small fragments of rock, can be seen to penetrate downwards into pockets in the weathered top of the underlying sandstone.

The thickness of Carboniferous rocks in this section amounts to approximately 170 ft. Nothing but debris and scree material is seen in the lower part of the stream.

Section B (Dearg Allt).—The section of Carboniferous rocks exposed along the steep western side of the Dearg Allt is not so complete as the preceding. The cornstone (Trias) is seen resting on 12 ft. of red breccia but below this there is a gap of about 30 ft. in which no rock is visible. Below this comes a succession of sandstone escarpments, with a total thickness of about 170 ft. The sandstones are yellowish and as a rule coarse-grained or pebbly and show here and there thin partings of shaly material, sometimes with rootlets. Irony concretions and clay galls are also present. These strata are very similar in general character to the arenaceous beds of Section A. The general succession is given in tabular form below but it should be noted that the banks are much overgrown and that between the escarpments of gritty sandstone there may, in some cases at least, be bands of shaly material concealed by vegetation :—

Section in Dearg Allt

		Fms.	Ft.	In.
Trias (lower part)	Cornstone	—	—	—
	Breccia, red; with angular fragments of schist, etc. at least	2	0	0
	Gap (junction of Trias and Carboniferous here) say	5	0	0
Carboniferous	Sandstone	1	4	0
	Sandstone, with pebbly layers	11	4	0
	Sandstone, coarse; with nodules of grey shale	0	1	0
	Sandstone, with shaly partings at top and bands of pebbly conglomerate...	5	5	0
	Sandstone, coarse, pebbly ... ... at least	1	4	0
	Shales, sandy, light-coloured ... ... 1 in. or	0	0	2
	Sandstone, coarse, irony; haematite layer at base 3 in. to	0	0	6
	Shales, sandy, light-coloured; some rootlets ... up to	0	0	5
	Sandstone, reddish, gritty ... ... at least	1	3	0
	Gap of a few feet	—	—	
	Sandstone	5	0	0

The sequence is interrupted at this point by a fault, on the south side of which the following interesting section is exposed in a low bank at the burn-side, at about the 150-ft. level :—

	Ft.	In.
Sandstone, greenish, clayey ... ... at least	2	0
Shales, sandy; occasional plant-remains	1	0
Shales, grey; abundant plant-remains	1	9
Fireclay, coaly	0	1
Shales, bluish, micaceous	0	9
Shales, sandy; some plant-remains	1	0
Shales, pale-coloured and slightly "burnt"	0	3

A thin intrusion, in two leaves, occurs just below these beds, but no further sediments are exposed, the lower part of the burn showing only loose detrital material.

Section C (on foreshore, west of Inninmore Cottage).—About 300 yds. west of Inninmore Cottage there is a good section on the foreshore showing :—

	Ft.	In.
Sandstone, fine-grained ... ... about	7	0
Sandstone, coarse, gritty ; showing carious weathering at top and ironstone nodules below	7	0
Shales, hard, dark ; with plant-stems	0	6
Fireclay, sandy ; with ironstone balls	1	6
Shales, sandy, and sandstone ribs ; with irony nodules ; *Calamites*	9	0
Shaly sandstone ; with plant-remains ... about	2	5
Sandstone, hard, yellowish ... ... at least	5	0

The items bracketed correspond approximately to the lower 23 ft. of the section given in ' The Pre-Tertiary Geology of Mull, Loch Aline and Oban ' (1925, p. 56). Smaller sections a little farther west show that the sequence is continued upwards by a few feet of light-coloured sandstone and is underlain by 1 ft. of dark shale with obscure plants resting on 2 ft. of hard pale fireclay. The thickness of beds seen at this locality is approximately 40 to 43 ft.[1]

Section D (at old day-levels).—Three day-levels have at one time been driven into the bank at the back of the raised-beach platform, 300 yds. or so north-west of Inninmore Cottage. They are all close together and the middle one can still be easily entered and examined. A section obtained at this locality showed :—

	Ft.	In.
Sandstone, false-bedded ; with irony spots and carbonaceous streaks ... ... at least	9	0
Fireclay, grey	1	3
Coal, bright ... ... up to	0	4
Fireclay, soft, coaly ; with *Stigmaria*	0	4
Fireclay, hard, rooty	1	4
Fireclay, sandy	—	—
Gap of a few feet, including 1 ft. of sandy shales with abundant plant-remains		
Sandstone ; lower 3 ft. ochreous ... ... about	15	0
Sandy shales, black and rooty...	—	—

The old day-levels were opened out along the crop of the thin coal recorded above. A sample of this coal has been analysed in the Coal Survey Laboratories, Glasgow, and the results are quoted below[2] :—

Analysis of Coal

Specific Gravity	1.370
Proximate Analysis :—	
(Air-dried coal)	
Moisture	3.5
Volatile matter less moisture	32.4
" Fixed Carbon "	51.4
Ash	12.7
	100.0
Colour of ash	Pink

[1] Cf. Judd's estimate quoted on p. 75.
[2] By permission of the Director of Fuel Research.

Character of coke	Grey-black, no lustre, unswollen, fissured, cellular, fragile.

Ultimate Analysis :—

(Dry coal)

Ash...	13.16
Carbon	70.80
Carbon (as carbonate)	0.06
Hydrogen	4.65
Nitrogen	1.29
Sulphur (total)	1.17
Difference (oxygen and errors)	8.87
	100.00

Carbonate (CO_2) as percentage of air-dried coal ...	0.21
Total Chlorine as percentage of air-dried coal ...	0.02

Calorific Value :—

Air-dried coal. B.Th.U. per lb.	12,030

3. Thickness of Sediments

The strata exposed in Sections A, C and D appear to represent different portions of the Inninmore Carboniferous and, together with the few feet of strata seen on the south side of the small fault in the Dearg Allt (Section B), amount to approximately 250 ft. in thickness. The top of the Carboniferous in the Dearg Allt is roughly 310 ft. above O.D., and in the burn east of the Quarry Burn about 280 ft. These figures provide estimates of the minimum thickness of sediments at the eastern and at the western end of the outcrop. With an assumed average inclination of 6° the thickness of sediments above sea-level at these localities is roughly 430 ft. and 342 ft. respectively; or with an assumed average dip of 10°, 510 ft. and 384 ft. respectively. The Inninmore Carboniferous rocks are thus at least 300 ft. thick and may be as much as 500 ft.; how far they extend below sea-level we do not know.

4. Palaeontology

A careful re-examination of the various sections by the writers has led to the discovery of at least five new plant-horizons. These occur in the stream-section east of the Quarry Burn (the three highest plant-beds), in the Dearg Allt, and at the old day-levels. A complete list of the flora so far obtained is given in the following table, which includes the forms determined by Dr. Kidston and the results of an examination of the new material made by Dr. R. Crookall :—

Flora of Inninmore Carboniferous [1]

Plants	Localities			
	A Stream E. of Quarry Burn	B Dearg Allt	C Shore Section	D At Day-levels
Pteridospermeae and Filicales				
Adiantites bondi *Kidston* ...	—	C	—	—
,, sp.	—	C	—	—
Mariopteris muricata? (*Schlotheim*)	—	C	—	—
,, sp.	—	C	—	—
Neuropteris gigantea *Sternberg*	K	C	K	C
,, heterophylla? *Brongniart* ...	C	C	—	C
Sphenopteris striata *Gothan*	—	C	—	C
,, sp.	—	C	—	C
Lycopodiales				
Stigmaria ficoides (*Sternberg*)	—	—	K	—
Equisetales				
Annularia radiata *Brongniart*	—	—	C	—
Asterophyllites charaeformis ,, (*Sternberg*) ...	K	C	—	—
,, equisetiformis (*Schlotheim*)	—	—	K	—
,, grandis (*Sternberg*) ...	—	C	—	—
Calamites cisti *Brongniart* ...	—	—	K	—
,, suckowi *Brongniart*	—	—	K	—
,, schützeiformis *Kidst. and Jongm. forma* waldenburgensis *Kidston* ...	—	—	K	—
,, undulatus *Sternberg*	—	C	—	—
,, sp.	—	—	C	—
Cordaitales				
Cordaites principalis *Germar*	C	—	—	—
,, sp.	C	C	—	—
Artisia approximata (*Brongniart*)	—	—	K	—
Semina incertae sedis				
Carpolithus sp.	—	—	K	—
Samaropsis sp.	K C	—	—	—
Incertae sedis				
Pinnularia capillacea (*Lindley and Hutton*)	—	—	—	C

Dr. Kidston, as has been pointed out (p. 75), tentatively placed the Inninmore shore beds in his Lanarkian Series rather than in

[1] K indicates determinations by the late Dr. R. Kidston; C determinations by Dr. R. Crookall.

his Westphalian. It should be remembered that the dividing line between these two series was drawn by him "approximately at the Ell Coal"[1] (of Lanarkshire). Unfortunately the new material now available is not sufficiently diagnostic to decide the question definitely. The most interesting form so far obtained is undoubtedly *Adiantites bondi*. The type-specimen, and the only other one recorded, comes from a bed of shale below the Black Bed Coal at Dolly Lane, Leeds, and was referred by Kidston[2] to near the base of the Westphalian.[3] It is at present, however, much too rare a form to be used for correlation purposes. The other species are of common occurrence in the Coal Measures of the Central Valley, especially in the strata from the horizon of the Lanarkshire Ell Coal downwards (Kidston's Lanarkian). Some of them, such as *Sphenopteris striata* and *Calamites schützeiformis*, have also been recorded from the Millstone Grit.[4] The flora is certainly a small one but it is perhaps worth while noting that not a single form characteristic of the strata above the Ell Coal (*i.e.* Kidston's Westphalian) has been so far obtained. All that can be definitely stated meanwhile is that the Inninmore beds are of Upper Carboniferous age and possibly correspond to part of the Productive Coal Measures of the Central Valley.

The strata associated with the plant-beds of the Dearg Allt, the shore-section, and the section at the old day-levels all suggest comparison with the sediments of the Productive Coal Measures. The higher beds, exposed in the upper part of the Dearg Allt and in Section A are in the main coarse and frequently pebbly yellowish sandstones, with subordinate bands of shale often showing a lilac or purple tinge. They contain on certain horizons numerous shale galls or lenticles while occasional desiccation breccias occur indicating contemporaneous erosion. Not a single marine or fresh-water shell has been obtained in any part of the sequence. The sediments as a whole point to accumulation under shallow-water or deltaic conditions, possibly in a land-locked area on the fringes of the Coal Measure lagoons. The numerous irony concretions and the reddish colouration affecting many of the higher beds of shale especially may be ascribed to infiltration from the overlying Trias.

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[1] Kidston, R., in 'Economic Geology of the Central Coalfield of Scotland, Area V,' (*Mem. Geol. Surv.*), 1916, p. 126; 2nd Edit. (revised), 1926, p. 146. Dr. R. Crookall ('A Critical Revision of Kidston's Coal Measure Floras,' *Proc. Roy. Phys. Soc. Edin.*, vol. xxii, 1931, pp. 1-32) has recently proposed that the dividing line should be drawn at the lower horizon of the Auchingane or Mill Coal.

[2] Kidston, R., 'Fossil Plants of the Carboniferous Rocks of Great Britain,' (*Mem. Geol. Surv.*), Palaeontology, vol. ii, part ii, 1923, p. 192.

[3] The Black Bed Coal is also placed by Dr. D. A. Wray near the base of the Middle Coal Measures or Yorkian (=Westphalian) of the Yorkshire succession; see D. A. Wray, 'The Major Subdivisions of the Coal Measures in Yorkshire' *in* 'Summary of Progress, for 1931, (*Mem. Geol. Surv.*), 1932, pp. 56-69.

[4] *i.e.*, from above the 'plant-break,' the line adopted as the boundary between Upper and Lower Carboniferous; see 'Economic Geology of the Stirling and Clackmannan Coalfield,' (*Mem. Geol. Surv.*), 1932, p. 118.

VIII.—A THOMSONIZED INCLUSION FROM THE BLACKNESS SILL

BY

SIR JOHN FLETT, K.B.E., F.R.S.

Plate V.

IN 1918 a boring was made in the Oil-Shale Series of the Scottish Carboniferous at Blackness, West Lothian, on the south shore of the Firth of Forth about four miles east of Bo'ness. The principal features of this boring have been described by R. G. Carruthers and H. M. Cadell.[1] At a depth of 260 ft. it entered a ' whin sill ' which proved to be 164 ft. thick and consisted of teschenite and picrite.[2] Mr. David Tait collected specimens of the rocks passed through, and in the teschenite, at a depth of 107 ft. below the top of the sill, he obtained the material which is under description.

The thomsonized fragment was thought at first to be a thin vein of fine basalt such as occurs in the Dalmeny sill.[3] On closer inspection, however, it was seen to consist of a coarsely crystalline matrix with good cleavages, enclosing fine grains of a dark mineral, but the general appearance (apart from the cleavage) is not unlike that of a finely crystalline dark grey basalt. Only two pieces, about two inches in diameter, were obtained.

In microscopic section the rock consists of a matrix of thomsonite, in crystals nearly half an inch in length, in which are embedded grains of pyroxene, garnet, sphene and iron ores. With the thomsonite there is a limited amount of analcite and albite in the matrix. Calcite, or other colourless carbonates, chlorite and fibrous amphibole are probably of secondary origin.

The thomsonite was not recognized at first. It is colourless, with one good cleavage and another less perfect, usually straight extinction and refractive indices ranging from 1.528 to 1.536. The double refraction is about that of albite or of quartz. Twinning seems to occur not uncommonly and the twin plates are large and simple. The optical sign is positive. The optic axial angle was not measured exactly but is about 60°. The mineral has some resemblance to albite, but lacks the characteristic twinning, and to cordierite, from which it differs in optical sign and in the absence of pleochroic spots. When the slides were sent to Professor Tilley he suggested that the mineral was thomsonite, and this was confirmed by microchemical and optical

[1] Carruthers, R. G., in ' Oil Shales of the Lothians ' (*Mem. Geol. Surv.*), 3rd Edition, 1927, p. 75 ; H. M. Cadell, ' The Rocks of West Lothian,' 1925, p. 68, and ' The Geology of the Blackness District,' *Trans. Roy. Soc. Edin.*, vol. liii, 1922, p. 189.

[2] Flett, J. S., ' The Blackness Teschenite,' ' Summary of Progress ' for 1930 (*Mem. Geol. Surv.*), 1931, part III, p. 39.

[3] Flett, J. S., ' The Teschenite of Easter Dalmeny,' ' Summary of Progress ' for 1929 (*Mem. Geol. Surv.*), part III, 1930, p. 59.

tests made in comparison with specimens of crystallized thomsonite from Scottish localities. These tests were made on material separated from the rock fragment by floating in a liquid of specific gravity 2.53.

In the thomsonite matrix there is a great abundance of a greenish *pyroxene* in small grains rarely larger than a tenth of a millimetre across. Their colour varies from pale green to dark green and they are mostly in fresh condition. Only the largest grains show the pyroxene cleavage, but traces of good crystalline outlines are by no means infrequent. Greenish-brown *garnet* (grossularite) appears in some of the slides though not in all. It is in well formed dodecahedra, usually free from inclusions, though sometimes having a central cavity filled with thomsonite or carbonates. *Iron ores* occur in numerous small crystals and there is often a good deal of brownish *sphene*, in small lozenge-shaped individuals which may be attached to the grains of iron ore. Of the other minerals the only ones that call for notice are a few small crystals of *apatite* and *zircon*, scattered patches of cloudy *analcite*, and a small amount of *albite* in small crystals, simply twinned and mostly filling cavities or fissures.

In some of the microscopic slides, though not in all, there are numerous pseudomorphs consisting of an outer girdle of iron oxide or of pyrite enclosing a greenish mineral which seems to be chlorite. It is not certain what the original mineral was as it is never preserved, having apparently been destroyed during the pneumatolytic process that produced the thomsonite. It seems possible, however, that it was a mineral of the spinel group.

The most striking feature of the microscopic sections is the presence of rounded, clear, colourless spots. Around them the little pyroxene grains are often arranged tangentially. These spots occur in the colourless thomsonite matrix, which stretches unbroken across them and polarises uniformly in and around the spotted areas. They are distinguished from the thomsonite elsewhere by their rounded shapes and the absence of inclusions. Undoubtedly the spots are the remains of steam cavities which have been filled up by the gradual growth of the thomsonite. The whole matrix of the rock has evidently been replaced by coarsely crystalline thomsonite.

In its general composition the rock has many of the characters of a calc-silicate hornfels. The abundant minerals, grossularite, diopside and sphene, are all characteristic of such rocks. If the thomsonite is a later product it may probably have replaced some lime-bearing plagioclase such as bytownite or labradorite.

Two problems present themselves for solution. One of these is the original nature of the rock, and the second is the origin of its peculiar structure.

A chemical analysis is given below in Table I A along with four analyses of Houston Marl and one of a basalt of Hillhouse type from the volcanic series of the Bathgate Hills, to which also the Blackness Sill probably belongs.

TABLE I

	A	B	C	D	E	F
SiO_2	39.82	32.19	40.09	34.92	36.90	42.49
Al_2O_3	14.72	16.13	19.23	21.88	22.51	13.85
Fe_2O_3	2.21	2.52	5.82	5.10	6.33	2.59
FeO	5.28	4.66	3.42	2.33	0.42	9.32
MgO	7.30	3.13	4.97	3.56	3.93	11.21
CaO	13.32	12.75	10.87	11.82	10.84	9.76
Na_2O	2.63	0.65	3.02	3.56	2.99	2.39
K_2O	0.34	3.40	2.32	2.99	2.69	0.87
$H_2O+105°$... ...	6.93	3.73	—	—	—	3.35
$H_2O-105°$... ...	2.79	3.62	—	—	—	0.47
TiO_2	0.99	0.73	1.16	1.64	0.96	2.51
P_2O_5	1.01	0.33	0.21	0.11	0.16	0.61
MnO	0.22	0.23	—	—	—	0.29
CO_2	0.53	16.27	8.26	11.37	11.46	0.22
FeS_2	1.72	0.15	—	—	—	n.f.
Cr_2O_3	0.07	—	—	—	—	—
Li_2O	—	tr.	—	—	—	n.f.
BaO	—	—	—	—	—	0.04
Cl	—	—	—	—	—	—
C	—	0.23	—	—	—	—
SO_3	—	—	0.32	0.36	0.26	—
CoNiO	—	—	—	—	—	0.09
Loss and undet. ...	—	—	0.31	0.36	0.55	—
	99.88	100.72	100.00	100.00	100.00	100.06

A. Thomsonite-pyroxene-garnet Rock, Blackness No. 2 bore, at depth 367 ft. 6 in. (*Anal.* B. E. Dixon).

B. Houston Marl, from Blackness No. 2 bore. (*Anal.* E. G. Radley). *Trans. Edin. Geol. Soc.*, vol. xi, 1925, p. 331.

C. Houston Marl, green, Waterstone, N. of Ecclesmachan. (*Anal.* Ivison Macadam). H. M. Cadell, 'The Rocks of West Lothian,' 1925, p. 48.

D. Houston Marl, green, Railway-cutting, Dalmeny. (*Anal.* Ivison Macadam). Cadell, *loc. cit.*

E. Houston Marl, reddish, Waterstone, N. of Ecclesmachan. (*Anal.* Ivison Macadam). Cadell, *loc. cit.*

F. Olivine-basalt (Hillhouse type), Hillhouse Quarry, West Lothian. (*Anal.* E. G. Radley). 'Geology of the Glasgow District' (*Mem. Geol. Surv.*), 1911, p. 142.

It seems quite obvious from the composition, mineralogy and structure of the fragment, (a) that it is contact-altered and (b) that it is pneumatolysed or zeolitized. The vesicular structure may be explained in various ways. It may have been original, and in that case the rock was presumably a slaggy fragment of volcanic ash. There is no difficulty in finding a source for such a fragment, as Mr. Cadell's section[1] shows that the Binns Hill Ash occurs in two beds about 200 feet below the bottom of the Blackness Sill. Analysis F, Table I, gives the composition of an olivine-basalt such as might be expected to occur in the Binns

[1] Cadell, H. M., 'The Geology of the Blackness District,' *Trans. Roy. Soc. Edin.*, vol. liii, 1922, p. 194.

Hill Ash. Undoubtedly it shows a general similarity to the composition of the fragment under consideration. There is a deficiency of lime and a surplus of magnesia and there are also discrepancies in the titanium and iron oxides; but if we allow that the ashes might be decomposed and possibly also impregnated with carbonates and zeolites the chemical differences might be smoothed out.

The microscopical characters, however, are opposed to this explanation. The rock is much more like a calc-silicate hornfels than a contact-altered igneous rock. Numerous cases of the latter have been described in the Mull memoir[1] and in no case do they show abundant green diopside and grossularite: and these minerals could not have arisen from the pneumatolytic zeolitization of the rock-fragment. On the other hand, it is conceivable that the ashy deposit had contained abundant carbonates and zeolites. Dr. McLintock[2] has described many interesting occurrences of zeolitic basalts contact-altered by granophyre in Mull. In these he found garnet (grossularite), diopside, thomsonite (and prehnite after thomsonite), iron ores, sphene, albite (with epidote, hornblende, zeolites, etc.), an assemblage resembling in many ways that of the Blackness xenolith.

In the Mull rocks, however, it is the zeolites occupying steam cavities in the lavas that are thus transformed. In the Blackness xenolith these minerals occur in the rock-matrix between the steam cavities and not in the obliterated vesicles. The latter are occupied only by thomsonite; garnet and diopside do not occur in them. This feature can be seen distinctly in the photographs (Pl. V). To explain the phenomena it would be necessary to suppose that the whole matrix of the Blackness xenolith had been replaced by zeolites while the steam vesicles remained empty, a hypothesis which lacks the elements of probability.

If we turn to the alternative supposition—that the rock is a vesicular calc-silicate hornfels—it is not difficult to find a probable source for it. At a depth of 300 ft. below the sill the boring passed through the Houston Marls. This greenish calcareous clay has been fully described by Cadell,[3] who considers that it is partly of volcanic origin, a fine-grained, stratified, argillaceous basaltic tuff.

In Table I four analyses of this Marl are quoted. One of these was made by Radley for Sir Jethro Teall[4] who made a microscopic study of the rock. These analyses are not entirely similar though they do not differ more than might be expected in specimens taken at localities several miles apart, and from a bed that is 100 to 200 ft. thick. They have a general resemblance in composition to the Blackness xenolith when allowance is made for the loss of carbonic acid, dispelled by contact-action, and the

[1] 'The Tertiary and Post-Tertiary Geology of Mull' (*Mem. Geol. Surv.*), 1924, p. 160, etc.
[2] McLintock, W. F. P., 'On the Zeolites and associated Minerals from the Tertiary Lavas around Ben More, Mull,' *Trans. Roy. Soc. Edin.*, vol. li, 1915, p. 1.
[3] Cadell, H. M., 'The Rocks of West Lothian,' 1925, p. 47.
[4] Teall, J. J. H., 'Petrological Notes on the Houston Marl,' *Trans. Edin. Geol. Soc.*, vol. ix, 1925, p. 327

increase of combined water in the xenolith, introduced during the process of pneumatolysis. The xenolith also contains less alumina and potash but more magnesia than the Marl, but on the whole the analyses of the Marl agree better than that of the basalt with the peculiar features of the xenolith.

Contact-alteration of the Houston Marl might be expected to produce principally grossularite, diopside and a basic plagioclase (probably bytownite). From the basic plagioclases thomsonite might readily arise through pneumatolysis.

It is also necessary to consider the probable origin of the vesicular structure which is the most characteristic feature of the rock. As a rule inclusions of sedimentary material caught up in intrusive masses are changed into compact hornfelses; this is the case even with limestones which contain much carbonic acid that is set free during recrystallization. But limestones are very infusible except when they are very impure.

The Houston Marl, according to Radley's analysis (Table I, B), contains about 23 per cent. of volatile matter, carbonic acid and water. Experiments made for me by Dr. King of the Fuel Research Station showed that in a neutral atmosphere the Houston Marl softened at 1260°C and fused to a vesicular mass at 1310°C. The temperatures at which the Blackness teschenite behaved in a similar manner were 1160°C and 1245°C, the picrite 1230°C and 1300°C. Apparently the marl is slightly less fusible than the rocks of the sill, which may consequently have been at a temperature above its melting point when the fragment was caught up by the intrusion.

Instances of the fusion of shales and marls, complete or partial, by the action of fires in mines are by no means uncommon. The Scottish vitrified forts show that many rocks can be fused by comparatively simple methods. Dr. McLintock has recently described instances of the fusion of marls in Persia by the ignition of oil wells or gas wells.[1] In Scotland it is not uncommon to find that coal seams in contact with intrusive dykes and sills are changed to a blistery, coke-like mass, with many vesicles infilled with carbonates. The trap dykes of the West of Scotland not infrequently have fused the grits and arkoses with which they are in contact. The aluminous xenoliths in the tholeiite sills of Mull that have been described by Dr. H. H. Thomas[2] have been in some cases wholly or partly fused, and are sometimes vesicular, though seldom in a marked degree.

The inclusion under description, however, is the first case of fusion by a teschenite sill that has come to my notice.

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[1] McLintock, W. F. P., 'On the metamorphism produced by the combustion of hydrocarbons in the Tertiary sediments of south-west Persia,' *Mineralogical Magazine*, vol. xxiii, 1932, p. 207.

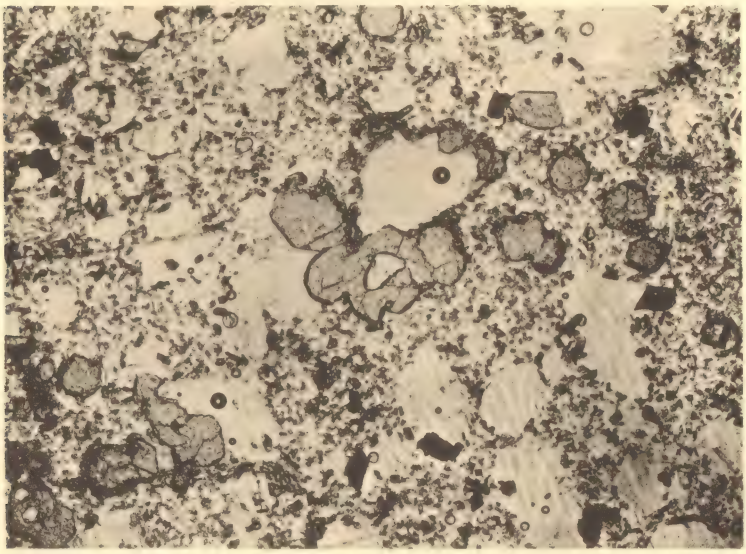
[2] Thomas, H. H., 'On certain Xenolithic Tertiary Minor Intrusions in the Island of Mull,' *Quart. Journ. Geol. Soc.*, vol. lxxviii, 1922, p. 229; 'The Tertiary and Post-Tertiary Geology of Mull' (*Mem. Geol. Surv.*), 1924, p. 268.

Description of Plate V

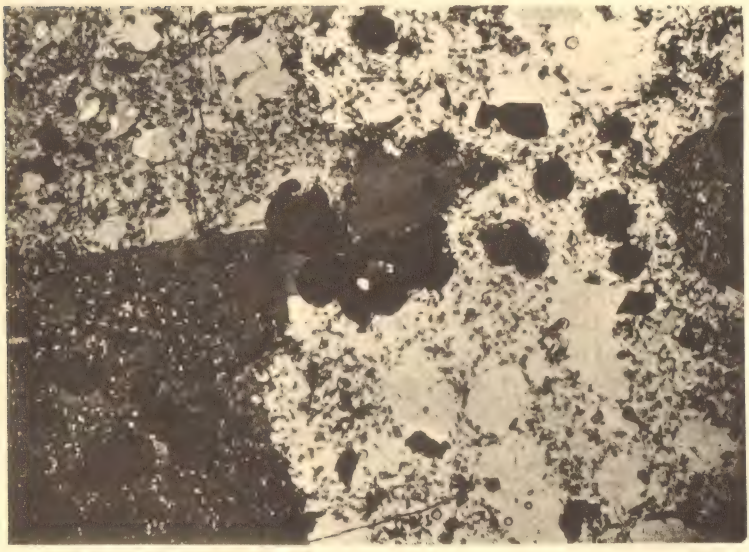
Fig. A. Photomicrograph of Thomsonized Xenolith from the Blackness Sill, ordinary light.

Fig. B. Same field, nicols crossed, magnified 28 diameters.

There is a small cavity with an air bubble above the centre of the field. The white matrix is thomsonite, which in the lower picture is seen to form broad spreads and apparently is in large-twinned individuals extinguishing uniformly over considerable areas. In the thomsonite lie many rounded garnets, of pale greenish brown colour. Their rough surfaces and dark edges are shown in Fig. A, and in Fig. B it is evident that they are practically isotropic. The abundant small granules are greenish diopside. The black spots in Fig. A are iron ores and pyrites. The clear rounded spots are visible in Fig. A, and Fig. B shows that the thomsonite has crystallized uniformly across them. A tangential arrangement of the diopside crystals around the clear spots can be perceived in several places. The garnet and diopside are not found in the spots but in the rock-matrix between them.



A. Ordinary Light, magnified 28 diameters.



B. Crossed nicols, magnified 28 diameters.

THOMSONIZED XENOLITH.

IX.—THE OCCURRENCE OF FOSSILIFEROUS PEBBLES OF SALOPIAN AGE IN THE PEEL SANDSTONES (ISLE OF MAN)

BY

PROFESSOR H. P. LEWIS, M.A., F.G.S.

Plates VI—VIII.

INTRODUCTION

OPINIONS are still at variance concerning the age of the sandstones, shales, conglomerates and concretionary limestones which are exposed for nearly a mile and a half in the cliffs north-east of Peel. The fossils which they contain appear in every instance to have been derived from pre-existing rocks, but they are of interest in that they include forms which have not been recorded from Northern Ireland or the Southern Uplands or even, in some cases, from the British Isles.

The Peel Sandstones have been placed in the Devonian, Lower Carboniferous and Permian by different authors. Towards the end of last century, the confident assertion by Boyd Dawkins in a series of papers that these beds are of Permian age, was called in question by Lamplugh, who, in the Geological Survey Memoir on the Isle of Man, followed Horne in expressing his conviction that the beds are not newer than Lower Carboniferous. My own unpublished investigations concerning the petrography of these rocks give results in support of Lamplugh's conclusions.

Lamplugh contested the statement of Boyd Dawkins that pebbles of Carboniferous Limestone occur in the conglomerates at Peel and are evidence of the post-Carboniferous age of the deposits, by the assertion that the evidence for the occurrence of Carboniferous Limestone in the conglomeratic bands ' is still unsatisfactory,' and by stating that the conglomerates may be intraformational. It is obvious that the fossils identified by Dawkins as *Euomphalus*?, *Orthis*?, *Spirifer*?, *Strophomena*?, a small finely ribbed *Chonetes* and portions of a small trilobite (*Griffithides glaber*), can not be regarded as proof of the Carboniferous age of the pebbles in which they occur. Lamplugh, judging from statements in the Memoir (1903) and in a discussion of Dawkins' paper (1902), seems to have been unable to decide whether some, at least, of the fossils were Upper Devonian and, if they were, whether they were contemporaneous. This opens up the question of the presence of marine deposits of Devonian age in the area and brings to mind the suggestion of Goodchild that marine conditions may possibly have existed in the Caledonian area in the Devonian. I have

found no Devonian fossils in the pebbles. Several of the fossils have a Devonian aspect, especially the septate Favositids, but associated with them in the limestone-pebbles in such a manner as to leave no doubt as to their contemporaneity, are definitely Lower Palaeozoic forms such as species of *Halysites* and *Plasmopora*.

Dawkins discovered a pebble-bed, which he believed belonged to the upper division, or Stack Series, of the Peel group, at the north-east end of White Strand. Mr. E. L. Gill identified all the fossils from this locality as species characteristic of the Keisley Limestone (1903). From the same locality I have obtained *Lichas sp.* and *Sowerbyella sp.* In the discussion of Mr. Gill's paper, Prof. P. F. Kendall expressed the following opinion: "I think that it is in the highest degree probable that the alleged Carboniferous species will be found to be actually Ordovician; the matrix seems to be of the Keisley type in all cases." So far as my own investigation extends, identifiable Carboniferous species are absent, but, excluding the pebble-bed at White Strand, the dominant forms occurring free or in the limestone pebbles in the Peel Sandstone are Salopian.

The Distribution of the Fossils

The derived fossils discussed in this paper are those collected during the official survey and preserved in the collection of the Geological Survey and Museum, and those which I have, personally, collected at different localities and from various horizons in the Peel group. No fossils have so far been recorded from exposures between the north-east end of White Strand and Lhoob y Reeast. The fossils here described, therefore, come from the Peel group at and to the west of Lhoob y Reeast. The rocks in this area were subdivided by Boyd Dawkins into an upper, or Stack Series, and a lower, or Peel Series; he also referred to the former as subdivision 'E,' and subdivided the latter into the groups 'D,' 'C,' 'B' and 'A,' in descending order. Group 'A' is the unexposed portion extending about a quarter of a mile inland beneath the drift.

Fossils occur in the 'Peel Series' only in some of the thin bands of conglomerate and conglomeratic breccia in the lower part of group 'B' at Creg Malin and Ballawhane, and near the top of 'D' near Traiae Fogog. In the lower bands the fossils are difficult to extract, but *Favosites* cf. *gothlandicus* Lamarck and *Heliolites interstinctus* (Linnaeus) have been identified in these beds. *Hallopora elegantula* (Hall) is the commonest fossil in the transition beds 'D,' between the Upper and the Lower Series.

The bulk of the fossils occur in the 'Stack Series.' They are not common and often their presence is only revealed by cutting sections of the pebbles. In some beds, associated concretionary cornstones make it difficult to detect the limestone-pebbles. The

isolated, rolled and broken individuals usually occur in a gravelly matrix. There is no doubt concerning their detrital origin. Rolled and fragmentary brachiopod-valves occur sparingly, but they are too poorly preserved to be identified with certainty. Crinoid ossicles are sometimes fairly common. The larger pebbles have a longer diameter of three inches or more. They are composed, mainly, of Bryozoa, encrinital remains, Stromatoporoids and corals set in a limestone-paste, which is usually somewhat stained by haematite.

List of fossils collected from the Stack Series

Localities: 1, cliff-section near the old lime-kiln, near Lhoob y Reeast; 2, cliff-sections 100 yards to 200 yards S.W. of the Stack.

Acervularia ananas (*Linnaeus*)	2
Chonophyllum *cf.* patellatum (*Schlotheim*)	1
Cystiphyllum cylindricum *Lonsdale*	1
Holmophyllum simplex *sp. nov.*	1
Phaulactis sp.	1, 2
Xylodes articulatus (*Wahlenberg*)	1, 2
Alveolites *cf.* labechei *Edwards and Haime*	1, 2
Favosites asper *d'Orbigny*	1, 2
,, gothlandicus *Lamarck, ? forma* forbesi *Edw. and Haime*	1, 2
,, *cf.* hisingeri *Edwards and Haime*	1, 2
Halysites catenulata (*Martini*)	2
Heliolites interstinctus (*Linnaeus*), two varieties	1, 2
Pachypora *cf.* cristata *Edwards and Haime*	1
Plasmopora scita *Edwards and Haime*	1
Syringopora *cf.* serpens (*Linnaeus*)	1, 2
Fistulipora sp....	1
Rhombopora spp.	1, 2
Dianulites petropolitana *Dybowski, var.* minor *var. nov.*	1
Hallopora elegantula (*Hall*)	1, 2
Monotrypa pulchella *Edwards and Haime*	1, 2
Stromatoporoidea, Crinoidea, Brachiopoda and ? Gastropoda ...	1, 2

The Source of the Fossils

Some of the tabulate corals and Bryozoa which have been identified have a long stratigraphical range, and they may have been derived from rocks of Bala or of Silurian age. The Rugosa, however, are characteristic Wenlock forms and they, with the majority of the other fossils named, constitute an assemblage which is typical of the Salopian deposits of the Wenlock, Dudley, Malvern and Gotland areas. Other considerations make it appear unlikely that the source of the material constituting the Peel Sandstones lay to the south or the south-east of the Manx area. In all probability the exposures from which the fossils were derived were situated at no great distance north or north-west of the Peel district.

At the time of the deposition of the Peel Sandstones, it appears, therefore, that, to the north-west of the Manx ridge, there existed rock-types similar in facies and in faunal content to the littoral Wenlock limestones of the western portion of the English Midlands. It is probable that only a small thickness of Valentian rocks (if any) intervened between these Wenlock beds and those of Keisley Limestone age, which contributed the fossiliferous pebbles occurring within a mile of the Stack at White Strand.

The occurrence among the derived fossils of a species of *Holmophyllum* Wedekind, a genus hitherto known only from Gotland, and of other forms pertaining to the calcareous development of the Salopian in the Baltic region, is a further point of interest.

Dr. F. L. Kitchin very kindly allowed me to make full use of all the fossils from Peel collected during the official survey of the Isle of Man, and I am much indebted to him for his help in this and in other ways in the production of this paper. From Dr. Stanley Smith I have received most valuable assistance in identifying some of the corals, and this I very gratefully acknowledge.

PALAEONTOLOGICAL NOTES

ANTHOZOA

RUGOSA

Acervularia A. F. Schweigger
('Beobachtungen auf Naturhistorischen Reisen,' Berlin, 1819)

Genotype: *Acervularia baltica* Schweigger, *op. cit.*, table vi (=*Madrepora ananas* Linnaeus, 1758, p. 797).

Acervularia ananas (Linnaeus)[1]

Plate VI, figs 1a, 1b.

A portion of a cerioid coral has been collected from the Stack Series which consists of a few corallites exhibiting in transverse sections all the characters described by Smith and Lang for this species. The largest corallite is 11 mm. in greatest diameter. There are two cycles of septa and about forty septa in all. Some of the major septa reach the axis, while the minor septa end at a short distance within the inner wall, or aulos, at which all the septa are dilated. Carinae are present, and a few dissepiments occur near the outer wall of each corallite.

[1] See Lang, W. D. and Stanley Smith, 'A Critical Revision of the Rugose Corals described by W. Lonsdale . . .', *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 451, fig. 3; also Stanley Smith and W. D. Lang, 'Silurian Corals.—The Genera *Xiphelasma*, gen. nov., and *Acervularia*, Schweigger . . .,' *Ann. Mag. Nat. Hist.*, Ser. 10, vol. viii, 1931, pp. 85-88.

Range.—Wenlock and Lower Ludlow, Gotland; Wenlock Limestone, England. So far as I am aware, *Acervularia* has not been recorded from the Silurian rocks of the Southern Uplands, Ireland or the Lake District.

Chonophyllum Edwards and Haime

(' Mon. Brit. Foss. Corals', Part i, 1850, p. lxix. *Palaeontograph. Soc.*)

Genotype: *Cyathophyllum perfoliatum* Goldfuss MS.

Chonophyllum cf. *patellatum* (Schlotheim)

Plate VI, figs. 2a, 2b.

This coral has forty major septa at a diameter of 2 cm. These septa are greatly thickened and extend to the axis, where their ends form a twisted columella. The thickened proximal portions of the septa together form a wide stereozone.

Range.—Wenlock.

Cystiphyllum Lonsdale

(In Murchison's ' Silurian System,' 1839, p. 691)

Genolectotype: *Cystiphyllum siluriense* Lonsdale, *op. cit.*, p. 691, pl. xvi bis, figs. 1, 1a.

Cystiphyllum cylindricum Lonsdale

Plate VI, figs. 3a, 3b.

A small cylindrical coral, 1 cm. in diameter, appears to belong to this species. In transverse and longitudinal sections the tabulae and dissepiments are seen to be the dominant structural elements. The septa are reduced to spinose ridges, except where both major and minor septa are distinguishable in the calicular portion of the coral and the septa appear to be complete.

Range.—Wenlock.

Holmophyllum Wedekind

(' Die Zoantharia Rugosa von Gotland,' *Sver. Geol. Undersökn.*, Ser. Ca, No. 19, 1927, p. 31)

Genotype: *Holmophyllum holmi* Wedekind, *op. cit.*, p. 31, pl. 4, figs. 6—8.

Holmophyllum simplex sp. nov.

Plates VI, figs. 6—11; VIII, figs. a—h.

Holotype: Specimen in the Department of Geology, British Museum (Nat. Hist.), registered R.30154 (Plate VI, fig. 6, and Plate VIII, fig. a).

Diagnosis.—*Holmophyllum,* showing characters which are more primitive than those of the genotype, and which, in the early stages resemble those of *Pholidophyllum* Lindström, 1870.

Description.—This coral is represented by a few corallites which are embedded in a stromatoporoid. The corallites are cylindrical and they are smaller than in *H. holmi.* The septal elements are also less oblique than in that species, especially at the distal end of the corallite, where they are separable into major and minor cycles, the major septa appearing, in some instances, to be complete (see Plate VIII, b). This may be due to their almost horizontal disposition. The minor septa are short and discontinuous. There are about forty-six septa, in all, at a diameter of 0.6 cm., eighteen at 3 mm. and twelve at 1.7 mm. In these early stages, transverse sections, in particular, bear a striking resemblance to some species of *Pholidophyllum* Lindström.

The tabulae have a pronounced sag proximally, and they are invaginated. They became introduced before the septal structures; the separation of the first tabula appears to have taken place in one instance, at least, when the corallite was about 0.5 mm. in diameter (see Plate VIII, h).

The ends of the tabulae, in the mature portion of the coral, rest against the dissepiments, which are finer than they are in *Storthygophyllum* Weissermel, 1894 (=*Xiphelasma* Smith and Lang, 1931).

Range.—This is the first record, so far as I am aware, of the genus *Holmophyllum* or even of the family Pholidophyllidae, in Britain. *H. holmi,* the only species of the genus hitherto described, is recorded by Prof. Wedekind from the Lau Beds of Gotland, which seem to be of Ludlow age. *H. simplex,* with its more primitive structure, may have come from a lower horizon.

The specimens on which the above description is based were collected by the writer from the Stack Series, below the old lime-kiln near Lhoob y Reeast; it is possible that the coral recorded in the fossil-list as *Amplexus* (near to *tortuosus*) in Lamplugh's Survey Memoir (1903), p. 276, may belong to this species, but it is very poorly preserved.

Phaulactis Ryder

('*Pycnactis, Mesactis, Phaulactis,* gen. nov., and *Dinophyllum,* Lind.,' *Ann. Mag, Nat. Hist.,* Ser. 9, vol. xviii, 1926, p. 392)

Genotype: *Phaulactis cyathophylloides* Ryder, *op. cit.*, p. 392, pl. xi, figs. 1—6; pl. xii, fig. 1.

Phaulactis sp.

Plate VI, figs. 4, 5a, 5b.

One specimen (see Plate VI, fig. 4) shows some resemblance to *Ph. cambrensis* Ryder (*op. cit.*, p. 393). At a diameter of 1.5 cm. there are thirty-three major septa which are thickened especially in the two cardinal quadrants. The minor septa penetrate the intrathecal area. There are about seven rows of dissepiments.

It is mainly on the evidence of the longitudinal section that the coral figured on Plate VI, figs. 5a and 5b is referred to *Phaulactis*. Comparison of fig. 5b with Dr. Smith's figure of *Ph.* near *angusta* (Lonsdale) *Quart. Journ. Geol. Soc.*, 1930, pl. xxvii, fig. 4, will show the similarity between these two forms. In transverse section the specimen from Peel has dissepimental tissue which is much looser and more irregular than in any described species of *Phaulactis*. Dr. S. Smith has called my attention to the resemblance which the coral shows to *Spongophyllum varium* Schlüter, a Devonian species, which, however, is a cerioid form.

Range.—Ph. cambrensis Ryder comes from the Wenlock of Penylan, Cardiff.

Xylodes Lang and Smith

(' A Critical Revision of the Rugose Corals described by W. Lonsdale...,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 461)

Genotype: *Madrepora articulata* Wahlenberg, 1821 (1819), p. 97.

Xylodes articulatus (Wahlenberg)[1]

Plate VI, figs. 12a, 12b.

Several separate corallites of this phaceloid coral have been found. The specimen figured has thirty-five major septa at a diameter of 1.3 cm., and thirty-two at a diameter of 0.8 cm. The major and the minor septa taper inwards, the former almost reaching the axis and being about twice the length of the latter. In longitudinal section the existence of an inner and an outer series of tabulae is well shown. The inner tabulae, about seven of which occur in a vertical distance of 2 mm., are convex distally, but

[1] For synonymy see Smith S. and R. Tremberth, ' On the Silurian Corals *Madreporites articulatus*, Wahlenberg, and *Madrepora truncata*, Linnaeus,' *Ann. Mag. Nat. Hist.*, Ser. 10, vol. iii, 1929, p. 363.

flat or sagging in the middle. The outer series is composed of plates, two to three in 2 mm., convex proximally and abutting against the inner tabulae and the innermost dissepiments (see Plate VI, fig. 12b).

Range.—Wenlock Limestone of the Wenlock, Dudley, Malvern, May Hill and Woolhope areas.

TABULATA

Alveolites Lamarck

(' Système des Animaux sans Vertèbres,' 1801, p. 375)

Genotype: *Alveolites suborbicularis* Lamarck, ' Histoire Naturelle des Animaux sans Vertèbres,' vol. ii, 1816, p. 186.

Alveolites cf. *labechei* Edwards and Haime[1]

Plate VI, fig. 13.

Fragments of a coral occur with oblique, compressed corallites, which average 1 mm. in longer and 0.4 mm. in shorter diameter, and which possess pointed septal spines. In tangential section (Plate VI, fig. 13) they are similar to *A. labechei*.

Range.—Wenlock.

Favosites Lamarck

(' Histoire Naturelle des Animaux sans Vertèbres,' vol. ii, 1816, p. 204)

Genotype: *Favosites gothlandicus* Lamarck, *op. cit.*, p. 206.

Favosites cf. *hisingeri* Edwards and Haime[2]

Plate VII, figs. 1, 2a, 2b.

Pieces of a massive *Favosites* occur in bryozoanal limestone-pebbles associated with typical Silurian forms such as *Plasmopora*. The corallites are polygonal, and up to 1.8 mm. in diameter. The walls of the corallites reach a thickness of 0.4 mm. In transverse sections twelve or more spinose lamellar septa are conspicuous. In longitudinal sections the tabulae are spaced from 0.15 to 0.3 mm. apart, and they are fairly regularly arranged; the septal spines can be seen, and closely-set mural pores appear to be arranged in two vertical rows on each corallite face.

[1] ' A Monograph of the British Fossil Corals,' Part v, 1855, p. 262. *Palaeontographical Society.*

[2] *Op. cit.*, Part v, 1855, p. 259.

The specimens figured were collected by Lamplugh from the Stack Series at Lhoob y Reeast (Geol. Surv. Coll., 52926 and 52927).

Range.—*F. hisingeri* is recorded by Edwards and Haime from the Wenlock.

Favosites gothlandicus Lam., ? forma *forbesi* Edw. and Haime[1]

This coral, of which one or two specimens have been found, for example, Geol. Surv. No. 52928, may be a form of *F. gothlandicus* with small corallites. In a specimen which I collected, the corallites are up to 1.5 mm. in diameter, with walls 0.2 mm. in thickness. Each corallite contains numerous septal spines. The tabulae occur at from 0.4 to 0.8 mm. apart. According to Dr. Smith, forma *forbesi* has larger corallites, but it is septate and has tabulae 0.4 to 1 mm. apart.

Range.—*F. gothlandicus,* forma *forbesi* is a Salopian form.

Favosites asper d'Orbigny[2]

Plate VI, figs. 14a, 14b.

A massive pyriform favositid in my collection can be referred to this species. The corallites are polygonal and vary from 0.65 mm. to 1 mm. in diameter, and the thickness of their walls is about 0.15 mm. Each corallite contains septal spines, usually twelve can be seen in transverse sections. The tabulae are spaced at intervals of from 0.25 mm. to 1 mm. The smallness and variation in size of the corallites, and the spacing of the tabulae are in agreement with *F. asper,* which, however, has not, typically, well developed septal structures.

Range.—*F. asper* occurs in the Upper Valentian and the Wenlock. It has been recorded from the Upper Ordovician and Valentian of the Southern Uplands (Peach and Horne, 1899).

Halysites Fischer von Waldheim

(' Zoognosia tabulis synopticis illustrata . . .' 3rd Ed., vol. i, Moscow, 1813, p. 387 [as *Alyssites*])

Genotype: *Tubipora catenularia* Linnaeus, 1767, p. 1270 (=*Millepora . . . concatenatis* Linnaeus, 1745, p. 34, fig. xx).

[1] See Stanley Smith, ' Some Valentian Corals from Shropshire and Montgomeryshire . . .,' *Quart. Journ. Geol. Soc.*, vol. lxxxvi, 1930, p. 318.
[2] See Edwards and Haime, *op. cit.*, Part v, 1855, p. 257.

Halysites catenulata (Martini)

Plate VII, figs. 3a, 3b.

There occur isolated lamellae of a form in which the corallites agree in structure and in size with *Fungites catenulatus* Martini.[1] In the specimen from Peel the longer internal diameter of the corallites is about 1.6 mm. and the shorter 1.25 mm.; the walls of the corallites are nearly 0.4 mm. thick, and the tabulae 0.65 mm. apart. The small 'coenenchymal' tubes occur in pairs between the corallites, from which they are separated by walls 0.1 mm. to 0.2 mm. thick. These small corallites have a longer diameter of about 0.4 mm. and a shorter of 0.2 mm., and the tabulae within them are 0.35 mm. apart. The mode of branching of the lamellae is shown in Plate VII, fig. 3a, and the arrangement of the tabulae in fig. 3b.

Range.—Upper Valentian and Wenlock. '*H. catenulata* (Linn.)' has been recorded from the Valentian rocks of the Southern Uplands (Peach and Horne, 1899).

Heliolites Dana

('United States Exploring Expedition during the years 1838-42, under the command of Charles Wilkes. Zoophytes,' by James D. Dana, p. 541, 1846)

Genotype: *Astrea porosa* Goldfuss[2] (=*Heliolites pyriforme*, etc., Guettard, 1770).

Heliolites interstinctus (Linnaeus)

Plate VII, figs. 4a, 4b, 5, 6.

Several specimens of *Heliolites* occur in the Peel Sandstone Series, but they all fall into one or other of the two groups of *Heliolites* described by Nicholson and Etheridge.[3] In the forms similar to 'group 1,' of these authors, the corallites are non-septate and cylindrical, varying from 1.5 to 2.0 mm. in diameter. The irregular, sub-polygonal coenenchymal tubes average 0.5 mm. in diameter (see Plate VII, figs. 5 and 6). Compare Nicholson and Etheridge, 1880, pl. xvi, figs. 3 and 4.

Contrasted with the septate group, or 'group 2' of *H. interstinctus*, the other Manx specimens have smaller corallites and finer coenenchymal tissue, otherwise they are similar. The septa are twelve in number and reach nearly to the middle of the corallites,

[1] Martini, F. H. W., 'Nachricht von einigen Churmärkischen Versteinerungen,' *Berlinisches Magazin*, vol. i, part 3, 1765, p. 268, pl. i, fig. 3.

[2] 'Petrefacta Germaniae,' vol. i, p. 64, pl. xxi, fig. 7, 1826.

[3] 'A Monograph of the Silurian Fossils of the Girvan District in Ayrshire,' fasc. 3, pp. 25—660, 1880.

which, therefore, are often difficult to distinguish without close scrutiny. The corallites are about 1.25 mm. in diameter, and the diameter of the coenenchyma averages about 0.25 mm. The spacing of the tabulae in each set of corallites is approximately eight in 2 mm. (see Plate VII, figs. 4a and 4b). Compare Nicholson and Etheridge, 1880, pl. xvi, figs. 2a and 2b.

Range.—Nicholson and Etheridge recorded both varieties of *H. interstinctus* from the Wenlock Limestone, and the septate form from Woodland Point, Girvan. The species has also been recorded from the Wenlock rocks of the Pentland Hills (1899).

Plasmopora Edwards and Haime

(' Mémoire sur les Polypiers . . . ,' *Comptes-rendus Acad. Sci.*, vol. xxix, 1849, p. 262)

Genotype: *Porites petalliformis* Lonsdale.

Plasmopora scita Edwards and Haime

Plate VI, figs. 15a, 15b.

One specimen in the Geological Survey collection agrees in all particulars, as seen in transverse section, with *P. scita* as described and figured by Nicholson and Etheridge (*op. cit.*, pp. 267-8, and fig. 8B). The corallites are 1 mm. to 1.2 mm. in diameter, and contain twelve more or less conspicuous septal spines projecting inwards from the crenulate walls. The walls of the smaller interstitial corallites are imperfect, and the average diameter of these corallites is about 0.3 mm., but their size is extremely variable. The main corallites are separated by intervals of from 0.3 to 1 mm.

Range.—Wenlock Limestone.

Syringopora Goldfuss

(' Petrefacta Germaniae,' vol. 1, 1826, p. 75)

Genolectotype: *Syringopora ramulosa* Goldfuss.

Syringopora cf. *serpens* (Linnaeus)

A coral occurs in the Stack Series with corallites similar in size to those of *S. serpens*. They are from 1.1 to 1.4 mm. in diameter, are circular in cross-section, and have walls from 0.25 to 0.3 mm. thick. The connecting-tubes in the form from Peel are, however, more numerous than in the form of this species described by Edwards and Haime.[1]

Range.—Wenlock.

[1] ' A Monograph of the British Fossil Corals,' part v, 1855, p. 275. *Palaeontographical Society.*

Bryozoa

cyclostomata Busk

Fistulipora M'Coy

(' On some new Genera and Species of Palaeozoic Corals and Foraminifera,' *Ann. Mag. Nat. Hist.*, Ser. 2, vol. iii, 1849, p. 130)

Genotype: *Fistulipora minor* M'Coy.

Fistulipora sp.

Plate VII, fig. 11.

Transverse and longitudinal sections of a bryozoan, having the characters of *Fistulipora,* occur in a micro-slide of a pebble from the Stack Series at Lhoob y Reeast, in the collection of the Geological Survey (M/750). The zooecia are rounded in cross-section, about 0.25 mm. in diameter, and contain diaphragms at intervals of about 0.2 mm. The mesopores are sub-angular in cross-section, average 0.1 mm. in diameter, and the vertical spacing of the diaphragms is also about 0.1 mm. In general, the zooecia are separated by intervals of from 0.1 to 0.3 mm.

Range.—The earliest species of *Fistulipora* occur in the Ordovician of Esthonia and America, but the genus is common only in the later Palaeozoic rocks. The form described here is probably of Wenlock age, judging by the fossils which are associated with it in the same slide.

cryptostomata Vine

Rhombopora Meek

(' Report on the Palaeontology of Eastern Nebraska,' Part ii of ' Final Rep. U.S. Geol. Surv. Nebraska,' p. 141, 1872)

Genotype: *Rhombopora lepidodendroides* Meek.

Rhombopora spp.

A bryozoan referable to this genus occurs with *Fistulipora sp.* in slide M/750, Geol. Surv. Coll., and I have collected similar forms as fragments of cylindrical stems, 2 to 3 mm. in diameter. In these the zooecia are from 0.13 to 0.17 mm. and from 0.25 to 0.4 mm. in diameter in different individuals, in which the spacing of the diaphragms is 0.2 to 0.3 mm. In the mature zone the walls are greatly thickened. Transverse and longitudinal sections show that the central axis is built up of a number of zooecial tubes and that these turn abruptly, through nearly a right-angle, as they approach the surface.

Range.—*Rhombopora* occurs in the Ordovician and Silurian, but it is commoner in the Upper Palaeozoic rocks. In the present instance, the associated fossils are of Wenlock age.

TREPOSTOMATA Ulrich

Dianulites Eichwald

(' Zoologia specialis . . .,' vol. i, 1829, p. 180)

Genotype: *Dianulites bicornis* Eichwald, *op. cit.*, p. 180, pl. ii, fig. 15.

Dianulites petropolitana Dybowski,[1] var. *minor* var. nov.

Plate VII, figs. 10a, 10b.

Holotype: The specimen here figured, in the Geological Department of the British Museum (Nat. Hist.), registered D. 33554.

Diagnosis.—*D. petropolitana* Dybowski in which the structure is from one-third to one-half as fine as in the species itself.

Description.—The zoarium is massive. The zooecia are about 0.15 mm. to 0.2 mm. in diameter; about ten to twelve occur in 2mm., instead of four in 2 mm., as in *D. petropolitana*. The intervals between the diaphragms vary from 0.18 to 0.35 mm., so that they are, as in the species, at distances varying between one and two tube-diameters. The walls are granulose, and hollow spines about 0.03 mm. thick occur in them in the mature part of the peripheral region of the zoarium. Usually about twenty can be observed in the wall surrounding a zooecium of average size. The mesopores are few and their distribution irregular. They are usually about 0.1 mm. wide, and the diaphragms are more closely set within them than they are in the zooecia.

Range.—*D. petropolitana* occurs in the Ordovician rocks of America and Russia. The variety described here may be later in age.

Hallopora Bassler

(' The early Palaeozoic Bryozoa of the Baltic Provinces,' *Bull U.S. Nat. Mus.*, No. 77, 1911, p. 325)

Genotype: *Callopora elegantula* Hall, ' Natural History of New York,' Palaeontology, vol. ii, 1852, p. 144.

[1] Dybowski, 1877, not *Diplotrypa petropolitana* Nicholson, 1879.

Hallopora elegantula (Hall)

Plate VII, figs. 9a, 9b.

This is the commonest of the bryozoa in the Peel Sandstone Series. It occurs in the Survey collection and I have obtained several specimens at different localities, in the beds ' D ' and ' E.' The specimens are fragmentary and appear originally to have formed part of massive, hemispherical zoaria.

The zooecia are polygonal to rounded and from 0.37 to 0.45 mm. in diameter. The mesopores are angular, variable in number and up to 0.25 mm. in diameter. In the zooecia the diaphragms are from 0.25 to 1.0 mm., and in the mesopores from 0.1 to 0.25 mm. apart.

Range.—Hall's type came from the Niagaran of New York and the species has been recorded from the Wenlock of England and Gotland.

Monotrypa Nicholson

(' On the Structure and Affinities of the " Tabulate Corals " of the Palaeozoic Period,' 1879, p. 293)

Genotype: *Chaetetes undulatus* Nicholson, ' On some of the Massive Forms of *Chaetetes*, from the Lower Silurian,' *Geol. Mag.*, 1875, p. 176.

Monotrypa pulchella Edwards and Haime

Plate VII, figs. 7a, 7b, 8.

Specimens which appear to be nearest to this species occur in the collection of the Geological Survey (52929, 52932, 52933), and in my own collection. The fragments seem to have been derived from a fairly large zoarium. Tangential sections show the zooecia to be from 0.2 to 0.3 mm. in diameter, with bilaminate walls about 0.06 mm. in thickness. In longitudinal section the diaphragms are seen to occur at intervals of about 0.35 mm.

Range.—Wenlock Limestone, Dudley.

Remarks.—Some of the specimens identified here as *M. pulchella* show considerable likeness to ' *Calamopora* ' *fibrosa*, var. *globosa* Goldfuss, which is a Devonian form.

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Explanations of Plates VI—VIII

Figured specimens, other than those in the Collection of the Geological Survey, or deposited in the British Museum (Nat. Hist.), are in my collection at the University College of Wales, Aberystwyth.

The localities are as stated on p. 93.

PLATE VI

Corals from the Stack Series, Peel, Isle of Man.

All figures, excepting fig. 15b, × 3 (approx.).

Fig.

1a, 1b. *Acervularia ananas* (Linnaeus), transverse sections of a few corallites from one corallum. Loc. 2. Page 94.

2a, 2b. *Chonophyllum* cf. *patellatum* (Schlotheim), transverse and longitudinal sections of one specimen. Loc. 1. Page 95.

3a, 3b. *Cystiphyllum cylindricum* Lonsdale, transverse and longitudinal sections of one specimen at an early stage. Loc. 1. Page 95.

4. *Phaulactis sp.*, transverse section. Loc. 2. Page 97.

5a, 5b. ? *Phaulactis sp.*, transverse and longitudinal sections. Loc. 1. Geol. Surv. Coll., both sections cut from specimen 52930, mounted on slide M/883. Page 97.

6. *Holmophyllum simplex* sp. nov., holotype, longitudinal section. Loc. 1. Brit. Mus. Coll., R. 30154. Page 96.

7 to 11. *Holmophyllum simplex* sp. nov., transverse sections at different stages of growth. Loc. 1. Fig. 7, Brit. Mus. Coll., R. 30155.

12a, 12b. *Xylodes articulatus* (Wahlenberg), transverse and longitudinal sections of one specimen. Loc. 2. Geol. Surv. Coll., 12a, slide M/888; 12b, slide M/889; cut from specimen 52934. Page 97.

13. *Alveolites* cf. *labechei* Edwards and Haime, tangential section. Loc 2. Page 98.

14a, 14b. *Favosites asper* d'Orbigny, transverse and longitudinal sections of one corallum. Loc. 2. Page 99.

15a, 15b. *Plasmopora scita* Edwards and Haime, transverse sections. Loc. 1. Fig. 15a, × 3; fig. 15b, × 17 (approx.). Geol. Surv. Coll., slide M/882, cut from specimen 52927. Page 101.

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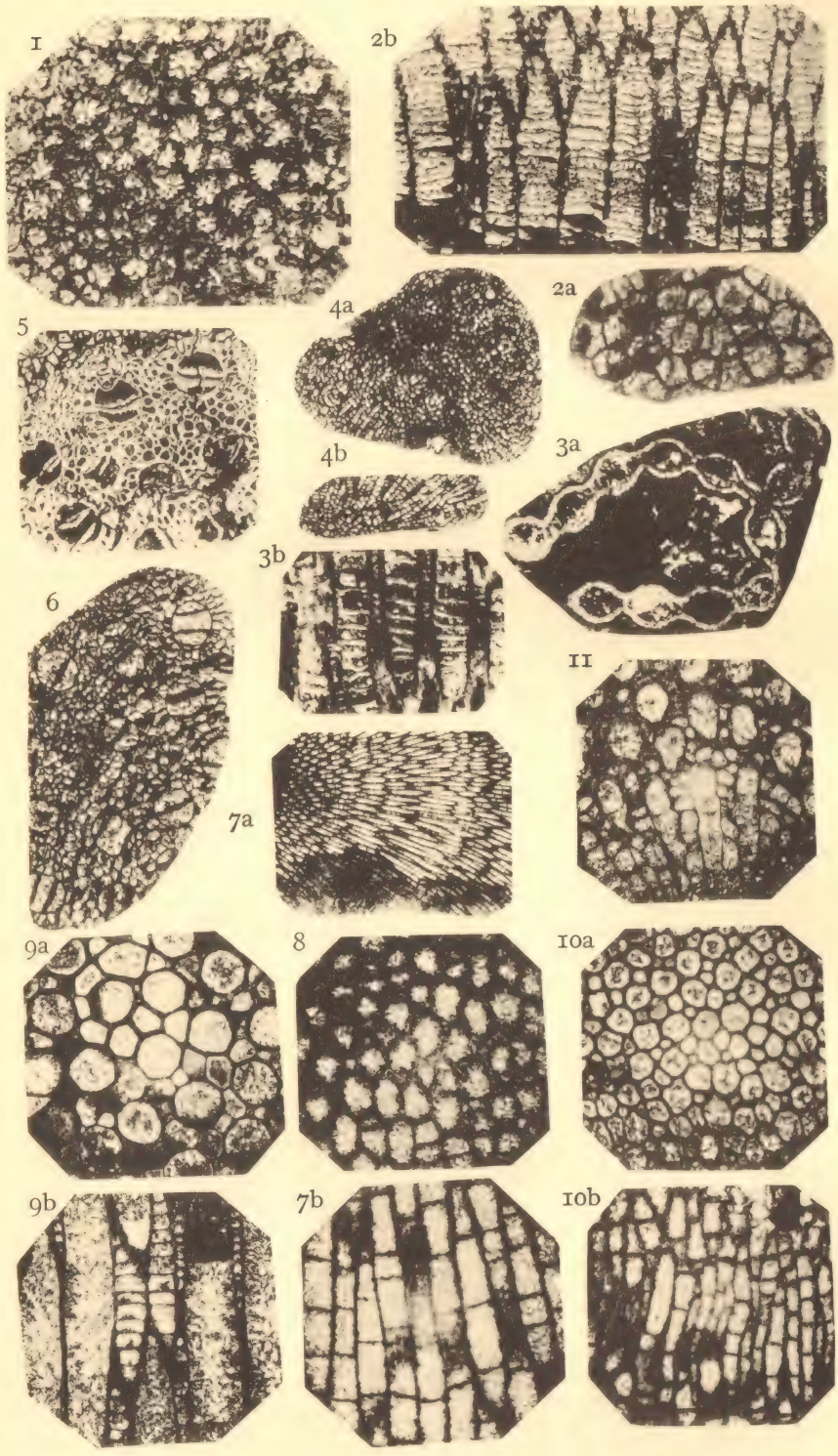

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PLATE VII

Bryozoa and Tabulate Corals from the Stack Series, Peel, Isle of Man.

All figures enlarged : figs. 1 to 7a, inclusive, × 3 (approx.) ; figs. 7b to 11, inclusive, × 17 (approx.).

Fig.

1. *Favosites* cf. *hisingeri* Edwards and Haime, transverse section. Loc. 1. Geol. Surv. Coll., slide M/879, cut from specimen 52926. Page 98.

2a, 2b. *Favosites* cf. *hisingeri* Edwards and Haime, transverse and longitudinal sections of several corallites of one corallum. Loc. 1. Geol. Surv. Coll., slides M/881, M/882, cut from specimen 52927.

3a, 3b. *Halysites catenulata* (Martini), transverse and longitudinal sections from one corallum. Loc. 2. Page 100.

4a, 4b. *Heliolites interstinctus* (Linnaeus), septate type ; transverse and longitudinal sections of one specimen. Loc. 1. Page 100.

5, 6. *Heliolites interstinctus* (Linnaeus), non-septate type, transverse sections. Loc. 1. Fig. 6, Geol. Surv. Coll., slide M/884, cut from specimen 52931.

7a, 7b. *Monotrypa pulchella* Edwards and Haime, vertical section. Loc. 1. Geol. Surv. Coll., slide M/886, cut from specimen 52932. Page 104.

8. *Monotrypa pulchella* Edwards and Haime, tangential section. Loc. 1. Geol. Surv. Coll., slide M/885, cut from specimen 52932.

9a, 9b. *Hallopora elegantula* (Hall), tangential and vertical sections from one zoarium. Beds ' D,' near Loc. 2. Page 104.

10a, 10b. *Dianulites petropolitana* Dybowski, var. *minor* var. nov., holotype ; tangential and vertical sections from one specimen. Loc. 1. Brit. Mus. Coll., D. 33554. Page 103.

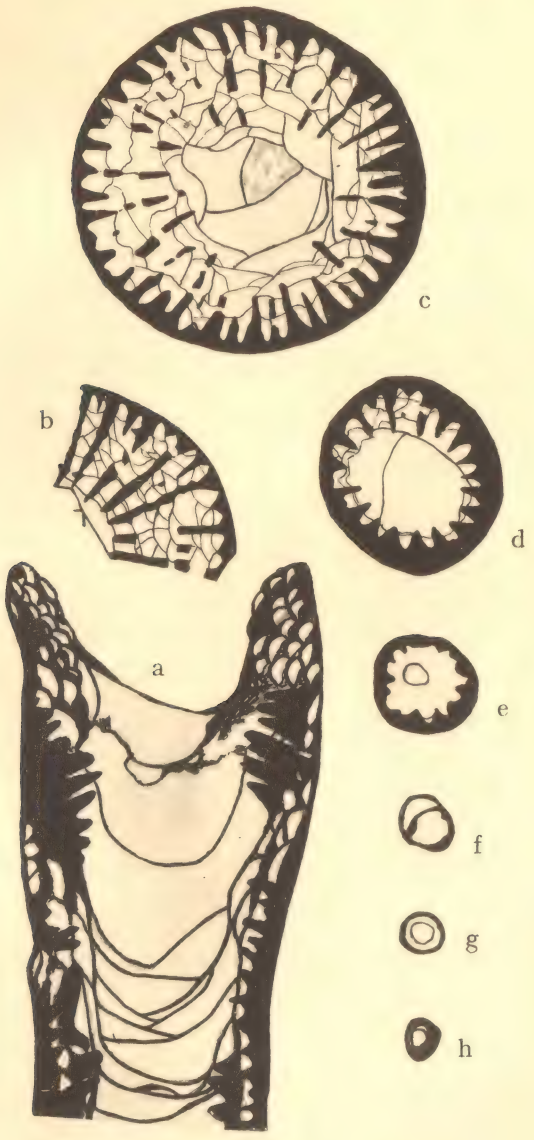
11. *Fistulipora sp.*, section showing tangential and longitudinal aspects. Loc. 1. Geol. Surv. Coll., slide M/750, cut from specimen 52935. Page 102.

PLATE VIII

Sections of *Holmophyllum simplex* sp. nov., from the Stack Series, Peel, Isle of Man ; all × 8 (approx.). Page 96. Plate vi, figs. 6-11.

a. Longitudinal section of the holotype, Brit. Mus. Coll., R.30154.

b to h. Transverse sections of growth-stages showing the ontogeny of the species and its probable phylogenetic relationship to the genus *Pholidophyllum* Lindström. Section c is from specimen R.30155, Brit. Mus. Collection.



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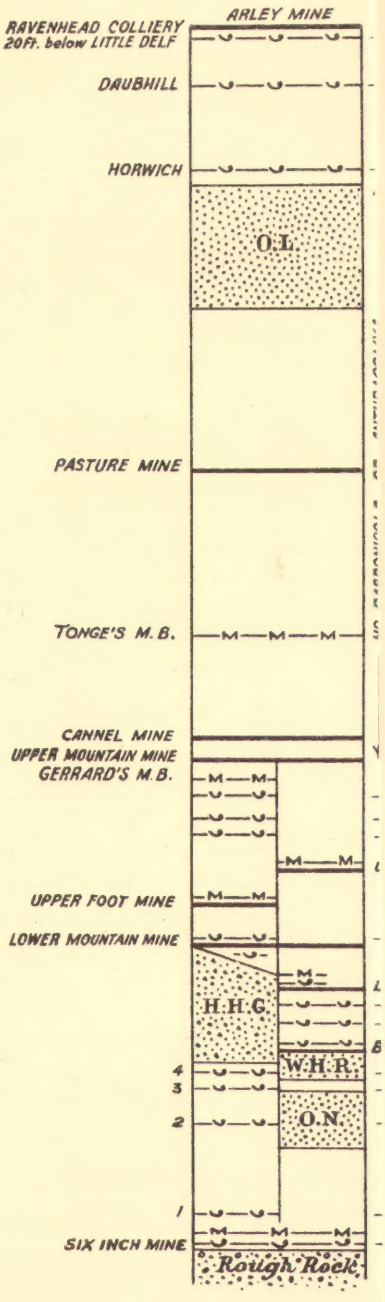

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